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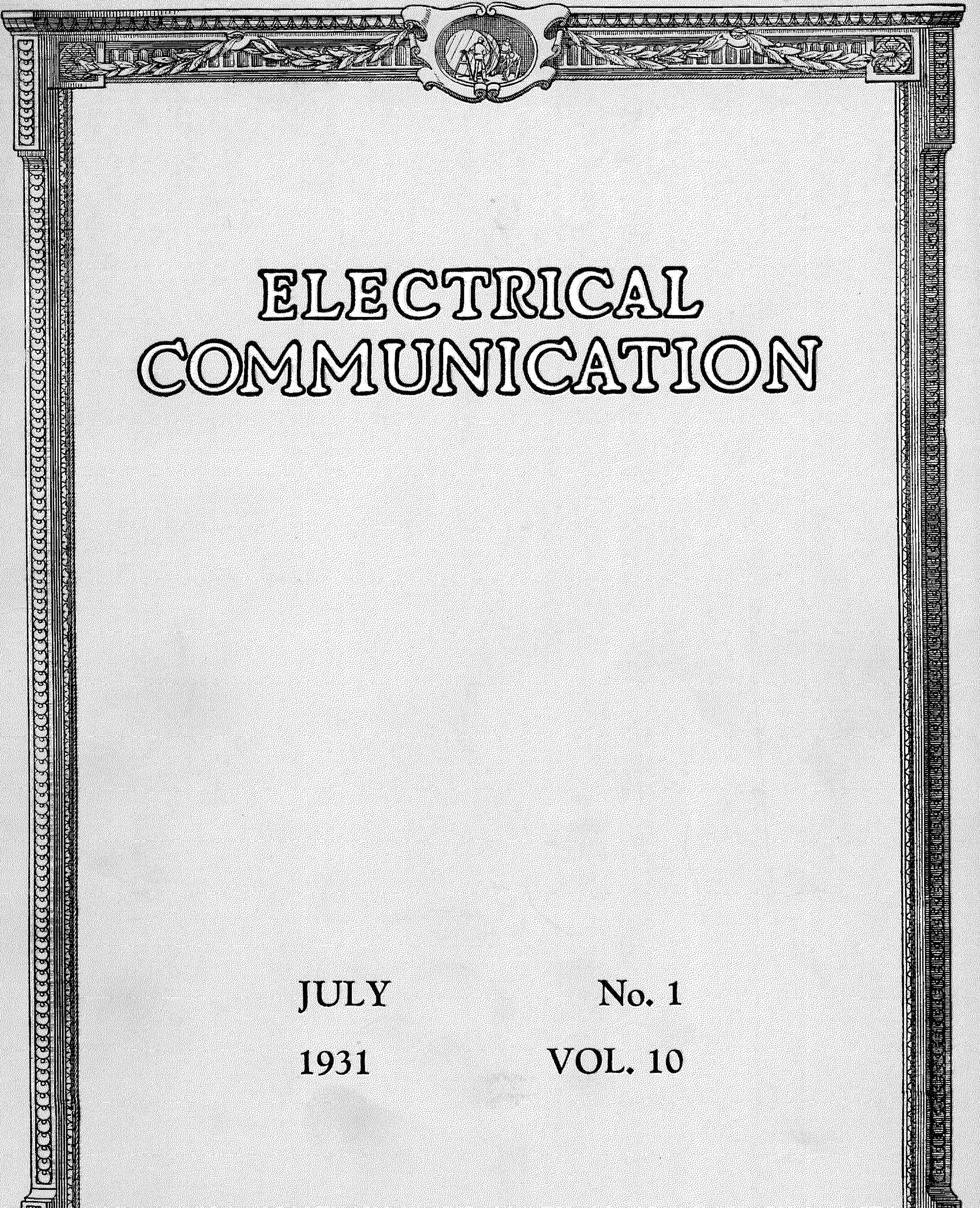

ELECTRICAL COMMUNICATION

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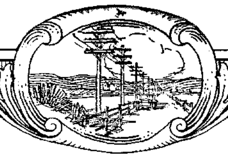

ELECTRICAL COMMUNICATION

A Journal of Progress in the Telephone, Telegraph and Radio Art

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CONTENTS

PAGE

The Single Side-band System Applied to Short Wave-lengths 3
By A. H. Reeves

Micro-ray Radio 20

The Practical Value of the Proximity Loss in Parallel Go and Return Conductors 22
By J. K. Webb, M.Sc., A.M.I.E.E.

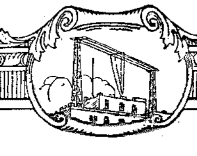
Public Service of Phototelegraphy in Japan 26
By Sannosuke Inada

An Early Television and Picture Transmission Proposal 34

Ten Years of Full Automatic Telephone Service in Oslo 36
By M. L. Kristiansen

Telephone Condensers 39
By R. E. W. Maddison and S. Chapman

Telephone and Telegraph Statistics of the World 45



INTERNATIONAL TELEPHONE BUILDING
67 Broad Street, New York

The Single Side-band System Applied to Short Wavelengths

By A. H. REEVES

General Advantages of Single Side-band

THE theory of the "single side-band" principle of telephony was worked out by John R. Carson some years ago, and was first applied to carrier communication on wire lines, its chief advantage in this connection being that twice as many speech channels can be put into the same total band width as when using direct modulation with both side-bands. Since that date it has also been applied with considerable success to radio telephony on long wavelengths, in particular to the long wave New York-London commercial telephone circuit. It is, in fact, difficult to see how this circuit could be operated successfully without using the single side-band method, since, on long wavelengths, it would be a matter of some difficulty to obtain an antenna resonance curve passing both speech side-bands.

In radio work the halving of the band width given by the single side-band system assumed considerable importance as soon as the ether began to get crowded. An additional advantage for radio work is the increased efficiency due to suppressing the carrier and one side-band.

With the high power vacuum tubes now in use, at any rate of the water- or oil-cooled types, the factor limiting the transmitter output is the peak current or peak voltage on the plates of the tubes in the last stage of the transmitter. When this condition applies, it can easily be shown that, for a given peak power, an antenna gain in signal-to-noise ratio of at least 9 decibels is obtained by using the single side-band system, as compared with the use of transmitted carrier and two side-bands. A short analysis showing this result is given in Appendix I.

A further advantage, important in the case of a high powered transmitter, is the reduction of the power consumed when the carrier is suppressed. In the case of the low power modulation system, followed by stages of high frequency amplification, the last amplifier stage at least is usually of the class-3 type, i.e., the tubes in the last stage are biassed nearly to "cut-off." The anode currents in these tubes, therefore, are quite small in the absence of modulation, rising to peak values at intervals during speech, giving an average power consumption considerably less than that of the transmitted carrier method, where the anode currents do not change during modulation.

Difficulties of Application to Short-wave Work

The single side-band method has never yet been applied commercially to short wavelengths. The reason for this delay in what might seem to be an obvious application of the older art to the wavelengths now in use is probably twofold. In the first place, at any rate until recently, the saving of band width has not been a very important consideration on short wavelengths, as the total band width available at frequencies of the order of 10 to 20 megacycles is many times greater than that which was available on the long wavelengths.

The second reason has probably been the technical difficulty of obtaining local oscillators to re-supply the carrier frequency at the receiver in a sufficiently good state of synchronism with the suppressed carrier at the transmitter. If the re-supplied carrier frequency differs from the original carrier by more than about 20 cycles per second, noticeably bad quality—even when judged by the standards of "commercial" speech—inevitably results. At frequencies of the order of 60 kilocycles per second the synchronising problem presents no difficulty, necessitating merely a precision of one part in 3000. Any good local oscillator will give this stability of frequency quite easily over fairly long periods of time.

When the short-wave case is considered, however, it will be seen at once that the problem is much more difficult. On a wavelength of 15 metres the precision required amounts to one part in one million, a degree of frequency stability quite difficult to obtain on a "commercial" basis, even when using the most modern methods. It is, in fact, this synchronising problem which is the chief technical difficulty to be overcome in applying "single side-band" to short waves.

Advantages in Short-wave Work

Let us now consider some further advantages possessed by the single side-band method when used on short wavelengths which do not apply to the older long-wave case.

Fading

Short-wave fading may be divided roughly into two types:—

(1) Synchronous fading, in which all frequencies throughout the particular band width rise and fall simultaneously in amplitude.
(2) Selective fading, where the rise and fall in amplitude at the various frequencies in the range is more or less random.

With synchronous fading, without a local carrier oscillator, the extent of the resulting fade of the audio frequencies is double that when a local carrier oscillator is used, the fading being expressed in decibels. (This can easily be seen by referring to the expression for the audio voltage given in Appendix I.) This is a fairly important advantage, though not so great as it might at first appear. Modern practice in short-wave receiver design is such that the synchronous fading is already very largely taken care of by the use of some kind of automatic gain control. The effect of such a device, operated automatically by the carrier amplitude, is to change the gain of the receiver inversely with respect to the signal strength received, so that the resultant speech has a very nearly constant strength.

With an efficient automatic gain control practically the only noticeable effect of synchronous fading (except when it is very deep) is a change in the strength of the background noise. This noise fluctuation may, however, prove quite troublesome to a listener, so that the carrier suppressed system, which halves this noise fluctuation, has an advantage in this respect.

Distortion

It is, however, during selective fading that the suppressed carrier method gives the most noticeable improvement. By the older method the carrier frequency fades out almost completely for intervals of time sometimes approaching half a second, while the side-bands remain. The output of the speech detector, being intermodulation products of all the frequencies at the detector input, then shows second harmonics and other terms which may be considerably stronger than the fundamental speech frequencies. The resultant distortion is sometimes quite serious, this bad effect being most noticeable when some type of privacy system involving a frequency inversion is used.

This will be made clear by reference to the following example: Take the case of a simple inversion system in the range 300 to 3,000 cycles per second, in which 300 cycles is transmitted as 2,700, and vice versa. Consider a speech component at 1,900 cycles per second; after inversion we shall have 1,100 cycles, with which the transmitter will be modulated. In the receiving detector, when the carrier fades out selectively, the second harmonic at 2,200 cycles may be much stronger than the fundamental at 1,100; this resultant 2,200 cycles will be transformed into 800 cycles by the receiving inverter. We will have then at the receiving terminal a small fundamental frequency of 1,900 cycles, accompanied by a strong unwanted frequency at 800 cycles.

We must now take into account the fact that the ear seems to be disturbed much less by true harmonics or true intermodulation products of the original speech frequencies than by any other frequencies not having this relation. This effect is possibly due to the fact that the ear itself produces true intermodulation terms, and as the response of the ear is logarithmic, a few more harmonics do not have much effect. However this may be, experiment shows that any system producing undesired frequencies not having true harmonic relationship with the original speech, causes such noticeable distortion that a simple inversion system cannot be used successfully on short-wave radio links when there is serious selective fading.

It may be of interest to note here that to overcome this difficulty on the Madrid-Buenos Aires link, the International Telephone and Telegraph Corporation abandoned the simple inversion system, and is now using instead a displacement of the side-bands by 3,000 cycles away from the carrier. By this method the original amount of secrecy is maintained, but the harmonics and intermodulation terms produced in the receiving detector and elsewhere are no longer in the audible range. Displacing the side-bands in this way, while giving reasonable privacy with good quality, has the disadvantage of requiring double the usual band width.

The same remarks also apply to any secrecy scheme, in which frequencies are produced in the output of the receiving detector.

INCREASED SELECTIVITY

A further problem which is not solved by the single side-band method itself, but which is easily solved at the same time, is that of increasing the selectivity of the receiver approximately to the theoretical limit. In order to receive the side-bands at "commercial" speech quality on the double side-band system, it is necessary, on theoretical grounds, to transmit and receive a band width of slightly less than 6 kilocycles. To receive the whole of this band, and this band only, requires, of course, a good stability of the transmitted carrier frequency and equal stability, accompanied by very accurate tuning, of the receiver.

At present, the best commercial receiver is designed for a band width of about 8 kilocycles, a margin of 1 kilocycle on each side of the transmitted band being necessary to allow for slight frequency changes in the transmitter and slight changes of tuning at the receiver. There are many commercial short-wave receivers in use, moreover, of which the band width is nearer to 12 or 15 kilocycles. It is true that this increase of band width does not appreciably increase the receiver background noise level, as the only noise needing consideration, as mentioned above, is that due to the noise impulses beating with this carrier; and the impulses spaced more than 3 kilocycles from the carrier produce audio frequencies which can be cut out at a later stage by introducing a low pass filter. Reducing the band width to the theoretical limit, however, may greatly reduce interference due to other stations, and thus make possible closer spacing between adjacent channels.

INTERFERENCE WITH ADJACENT CHANNELS

Another advantage of the single side-band system is that the interference due to a side-band on receivers tuned to adjacent channels is less noticeable, in general, than the steady beat notes produced by neighbouring carriers.

EXTRA GAIN WHEN SELECTIVE FADING IS PRESENT

Lastly, as pointed out in Appendix I, during selective fading conditions a further gain in signal-to-noise ratio of up to 3 db. is frequently obtained.

A Commercial System

The object of this article is to describe one of the possible single side-band systems for use on short wavelengths, and to describe experiments carried out by the International Telephone and Telegraph Laboratories in conjunction with the Laboratories of Le Matériel Téléphonique, Paris, during the past year with this system, between the International Telephone and Telegraph Commercial Transmitting Station at Pozuelo del Rey, near Madrid, and an experimental receiving station at Trappes, near Paris. It is not claimed that the system to be described is by any means the only possible one, or indeed, that it is necessarily the best system for commercial telephony. Only the future can determine the relative merits of the various possible methods. It is claimed, however, that a commercial system has been worked out, and that the results so far obtained have been sufficiently successful for a fairly detailed description to be of interest.

A short general survey of the problem encountered will first be attempted, together with reasons for choosing, as a first experiment, the particular method detailed below. It is believed that in these experiments, synchronisation of the locally supplied carrier has, for the first time, been achieved automatically and for long periods of time. There are certain problems encountered in single side-band working which do not arise with the normal double side-band, transmitted carrier method, such as the reduction of unwanted frequencies, due to intermodulation in the transmitter to a sufficiently small value; these difficulties, however, are well known, and have already been studied during the single side-band work on long waves. For this reason, they will not be referred to in detail here. The fundamental new problem presented by short-wave single side-band is that of synchronisation, which, as already shown above, is not a difficult matter with long wavelengths, but with wavelengths of the order of 15 metres, presents a serious problem.

The Problem of Synchronisation

INDEPENDENT OSCILLATOR METHODS

There are two means of attacking the general synchronising problem. The first is to use at the transmitter and the receiver, independent oscillators of which the frequencies are so stable that when once they are adjusted to differ by only one part in a million, they will maintain this relation for comparatively long periods of time. This method, although by no means impossible, raises a somewhat difficult design and operating problem, even if the most modern means are employed.

It is true that by using the best modern quartz crystal oscillators, with accurate temperature control, this frequency stability has been obtained and even exceeded in the laboratory, but it is quite a different matter to maintain this high accuracy under the conditions of commercial operation. The same remarks apply to the other available frequency standards of high precision, *e.g.*, magneto-striction oscillators, tuning forks, oscillators automatically controlled by precision clocks, and the best purely electrical oscillators, accurately compensated for frequency changes. A solution is probably possible by all these methods, but it is not considered that such solutions would be convenient from a commercial standpoint.

PILOT METHODS

The second general method is by the use of some form of pilot signal transmitted in addition to the side-band and used automatically to synchronise the carrier supply oscillator at the receiver.

Let us consider in detail the possibilities of this method. Pilot signals may be divided into two classes:

(1) A pilot signal transmitted only during intervals when speech is absent.
(2) A continuously transmitted pilot signal.

The first type permits the use of the maximum energy supplied by the transmitter for the signal, but has the serious disadvantage that the resulting intervals during which there is no pilot may be longer than the minimum interval required to give the desired frequency control.

Any signal in the second category must fulfil two conditions:

(1) The peak voltage must be small compared with the peak voltage of the side-band; otherwise the available power in the side-band is appreciably reduced, and one of the chief advantages of the single side-band method begins to be lost.
(2) The presence of the pilot signal must not appreciably increase the band width required by the side-band.

We have, then, two classes of pilot signal fulfilling these conditions:

(*a*) A pilot signal at low frequency, by which is meant either a continuous wave modulated at low frequency, or two or more continuous waves beating together at a low frequency used as a synchronising signal.

In the term "low frequency" is included here the frequency given by a train of impulses. The resulting low frequency may be used in a number of ways, *e.g.*, an appropriate harmonic of the L.F. may be used as the required carrier, or the beat note may be used to drive a synchronous motor generator, the output frequency of which is suitably multiplied, and supplies the local carrier; but whatever method is used, the stages of frequency multiplication required make this system rather cumbersome for operating conditions, and furthermore, a small phase change in the low frequency gives some hundreds of cycles change in the high frequency. Also, a beat note dependent on the product of two or more transmitted continuous waves is more subject to synchronous fading than is a high frequency control signal.

(*b*) A pilot signal, consisting of one or more continuous waves of radio frequency, used directly to give or control the desired local carrier.

The continuous wave or waves may conveniently be at a frequency just outside the side-band, *e.g.*, 300 to 400 cycles on either side of the speech side-band. Or, if desired, a little of the original carrier may be transmitted, and used as the pilot signal. In any case, however, the peak power in the pilot signal should be at least

15 db. below the peak power of which the transmitter is capable. The utilisation of a signal of such weak power is not difficult from a signal-to-noise standpoint, owing to the fact that the signal is of one or more steady frequencies; circuits of very small band-widths may, therefore, be used to select them.

The band-width required for the side-band is about 3,000 cycles; but when choosing the band-width necessary for the pilot channel we have only to consider the maximum probable sudden fluctuation in transmitted frequency, *i.e.*, the fluctuation during the period in which the synchronizing circuit has not had time to take up this new stable position. A sudden fluctuation of 15 cycles per second is probably an outside limit, therefore, in the case of a reasonably good transmitter, so that the band-width required for the pilot signal is of the order of 30 cycles per second, *i.e.*, just one hundredth of the range required for the side-band.

As is pointed out in Appendix I, other things being equal, the energy in the background noise is proportional to the band-width, so that the ratio of signal-to-noise energies in the case of a pilot signal at a level 20 db. below the side-band will be just the same as the signal-to-noise ratio of the side-band itself. As the latter ratio must be, say, 10 to 15 db. for reasonably good speech, it is evident that the pilot will also be received under conditions in which the background noise does not prevent its utilisation.

Ways of Using a Pilot Signal

Some different possible ways of using such a pilot signal will now be considered. As is shown in the sketch of Fig. 1, the possible methods can again be divided into two classes:

(1) The selection, amplification and use of the pilot as the local carrier frequency, either directly in the case when some of the original carrier itself is transmitted, or by adding or subtracting the required audio frequency.

(2) The pilot may be used to synchronize a local oscillator.

In considering the relative merits of these two methods, an inherent problem in short-wave work presents itself, viz., that of selective fading. Occasions will frequently arise when any one given frequency will fade out below the noise level, for periods of time sometimes approaching half a second in length. Therefore, if only one pilot is used, some form of time constant must be added, so that the locally supplied carrier will continue at the desired frequency during the fading periods. In practice this has been found to be one of the chief difficulties in the whole problem. When using the pilot signal directly, this time constant must take the form of a resonant circuit of very low damping—extremely low, in fact, as the resonant time constant required must be greater than half a second. Such a resonant circuit is, of course, very difficult to obtain, even when quartz crystals are used as the resonant element.

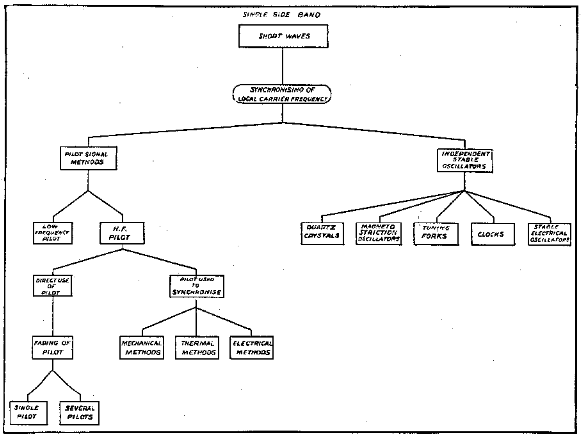
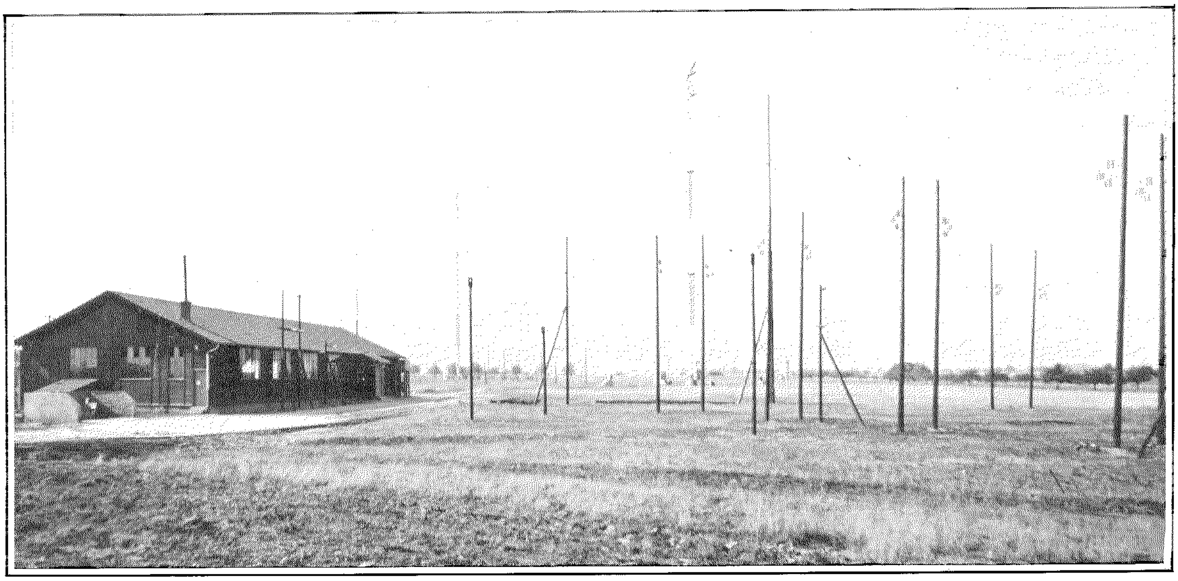


Figure 1

Even if such a resonant circuit were obtained, a large number would have to be used in parallel, with the resonance curves overlapping in order to cover the total probable fluctuation of the transmitted frequency. As this fluctuation must be assumed to be several hundred cycles in extent, and as the width of each resonance curve is less than half a cycle, it is clear that this solution becomes so cumbersome as to be impracticable.

Considerable improvement would, of course, be obtained by the use of two or more pilot signals, *e.g.*, two—one spaced at each end of the side-band. During selective fading these two pilots will only fade below the noise level simultaneously, at rare intervals, and for moments of very short duration. If arrangements are made, *e.g.*, by means of a relay, to use the greater of these two pilots to give the carrier, the time constant of the resonant circuit may



Radio Field Laboratory at Trappes. Antenna and Transmission Building.

be considerably reduced, but even then the solution is probably not a very practical one, at any rate whenever selective fading is present.

Automatic Synchronisation of Local Oscillator to the Pilot

Let us now detail the second way of using a high frequency pilot signal, *i.e.*, by allowing it to synchronise automatically a local oscillator. In this case it is clear at once that the problem of the time constant is very much simplified. The possible methods logically divide themselves into three classes:

(1) The methods relying on mechanical means.
(2) Methods using thermal effects.
(3) Purely electrical methods.

Before going into further detail we will consider the general applicability of the three methods. In comparing their relative merits, the first question that immediately arises is the value of the time constant required. This depends on whether one or more pilot channels are used; if one only is employed, the time constant of the frequency control circuit must be such, at any rate during the fading out of the pilot, that the oscillator frequency does not change more than 20 cycles during the maximum period of time that the fade is likely to continue—in this case about half a second. On the other hand the time constant must not be so long that it does not follow the fluctuations in the received frequency. These latter changes are due to two sources: first, accidental changes in the transmitter itself, and secondly, frequency changes due to the transmission path.

The first type of change with any transmitter having a good master oscillator is always very gradual; in fact, a rate of change of a few hundred cycles in one hour is the maximum that is tolerated by present practice. Let us take 10 cycles per second per minute as the upper limit for this rate of change. At present there is little data concerning the second type of fluctuation; however, it is probably quite rare for this change, due to rapid alterations in the length of the transmission path to exceed 10 cycles per second about its normal value, and for this change to take place in a period of time less than 1 to 2 seconds. Let us take 10 cycles per second as the upper limit of the rate of change of frequency, due to the transmission path. Inasmuch as the total frequency change due to this latter fluctuation rarely, if ever, exceeds 10 cycles per second we see at once that this effect may be neglected altogether from the standpoint of "commercial" speech. We may take, therefore, the rate of change of 10 cycles per second per minute as the maximum in practice that the time constant of the frequency control circuit must follow. While considering the other limit, the constant must be such that the frequencies can never change by more than 20 cycles in half a second.

It will now be clear that between these two limits an apparatus can be designed satisfactorily by any of the three methods, *i.e.*, mechanical, thermal, or purely electrical circuits. Some mechanical method, such as rotating a vernier condenser on the oscillator, in accordance with the frequency of the received pilot signal, is perhaps the most obvious solution. When comparing such a scheme with the other two methods it is difficult to see its superiority; in fact it has a number of incidental disadvantages, such as the noise pick-up in the receiver from relay clicks, motor noises, etc. It is probable also that the proper maintenance of such equipment by ordinary operators would be less satisfactory than the maintenance of a system working on either of the other two methods.

Let us consider next the thermal methods. One convenient way of doing this would be to cause the pilot frequency to change the temperature control point of the thermostat of the local oscillator, which in this case could be of the quartz crystal type. The thermal time constant obtained in this way could be given a suitable value in accordance with the two limits fixed above. Such an oscillator would have the advantage of extreme immunity from all changes of frequency, except the one desired. In many respects, in fact, such a thermal system has a lot to recommend it.

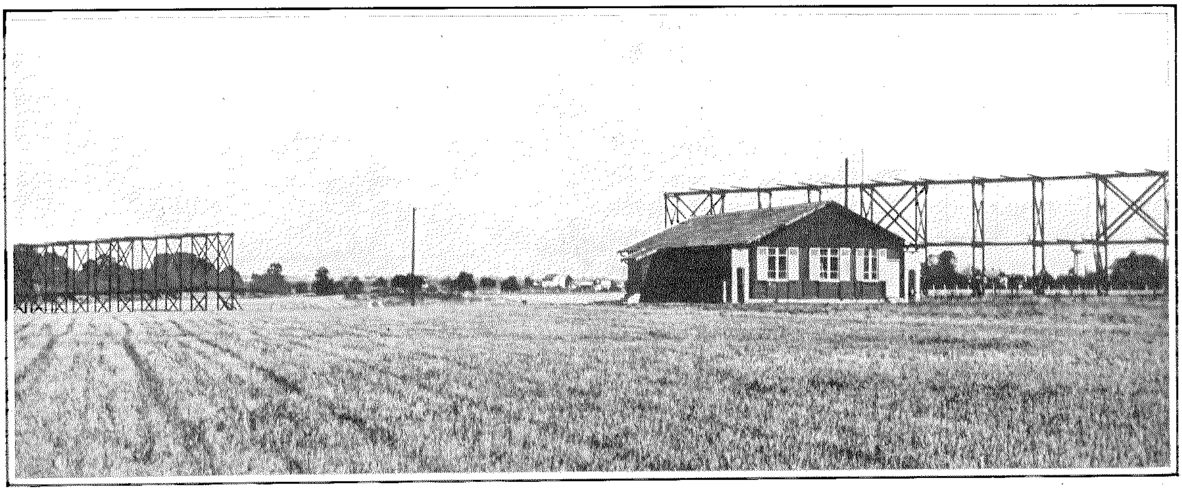
The frequency control can also be obtained fairly simply by purely electrical means, one of which, described in detail below, is the system used in the successful experiments which are now going to be discussed.

From the standpoint of "commercial" speech alone, the superiority of a purely electrical control method over the thermal system is doubtful. In the present case, the real reason that has governed the choice of system for preliminary experimentation is based on other considerations.

REASONS FOR CHOICE OF A PURELY ELECTRICAL METHOD

Considering the probable future development of radio during the next few years, it is almost certain that the single side-band method will be of utility, not only for commercial radio telephone links, but also for telegraphy, facsimile and television. It has been thought better, therefore, to start experiments on some system, the general methods of which will be applicable also at a later date to these other uses of radio.

In the case of these other applications it is not sufficient for the transmitted and received carriers to be synchronised with a precision of 20 cycles per second. This is true, of course, also, of high quality speech. For example, it is essential to avoid phase distortion, which can only be done by exact synchronisation of the frequencies and by keeping the phase variations between the two oscillators within narrow limits. This requirement at once rules out any method based on independent oscillators at each end of the link. It also practically rules out mechanical and



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thermal methods of using a pilot channel, as will now be explained.

In short-wave transmission, even when the signal is received by one path only, the phases of the side-band components are frequently distorted backwards and forwards about their normal values by this transmission path, which is not of constant length. If, however, reception by more than one route is prevented, the result is simply a variable "delay" introduced between the transmitter and receiver, *i.e.*, the phase distortion of each component is directly proportional to its frequency. Taking the case of a side-band 20,000 cycles wide in the range of 20 megacycles, this means that the phase change will be constant within 0.1 per cent. for all the side-band components and the pilot, and may be sufficiently compensated for by an equal phase correction at all frequencies. To achieve this result, it is necessary for the phase of the re-supplied carrier to follow the phase variations of the pilot signal.

These fluctuations may sometimes be quite rapid; hence it is essential under these conditions for the synchronising time constant at the receiver to be quite short, *i.e.*, of the order of a small fraction of a second—a time constant value very difficult, if not impossible, to obtain by a mechanical or thermal means. By electrical methods, however, it is comparatively simple to make the value of the time constant very flexible. It is probably quite easy to have it short enough to follow all variations met with in practice.

Although the system used by the International Telephone and Telegraph Laboratories, and described below, is not one of exact synchronisation, it is a purely electrical method, which can be changed at a later date when required, in order to synchronise exactly. Another desirable feature is for the time constant to be variable when following exactly the fluctuations of phase and frequency. Due to the transmission path, the constant must be quite short, but on the other hand during the fades-out of the pilot signal the time constant must be long enough for the oscillator to maintain its frequency and phase within the required limits. Clearly this can only be carried out by means of a time constant, the value of which is varied automatically during these fades-out. This particular feature is only obtainable at all easily by purely electrical methods.

By a mechanical means, we could, of course, make the time constant longer or infinite during the fades, *e.g.*, by cutting off the mechanical control of the tuning condenser altogether by means of a clutch; but such devices operate relatively slowly, and in any case, as stated above, the time constant cannot easily be made short enough by such means when the level of the pilot signal is high. It is very difficult to conceive of a simple way to vary the time constant by thermal methods.

Some Purely Electrical Methods

Let us next consider several possible purely electrical ways of changing the oscillator frequency or phase. Perhaps the most obvious solution is to use an iron core oscillator for changing the frequency by partially saturating the core. This method, however, is not suitable except at comparatively low frequencies.

A second possible means is to use the phenomenon possessed to some extent by any electrical oscillator, *i.e.*, a change of frequency with change of grid bias. By this method, however, it is difficult to obtain more than a very small frequency change. The third method, the one used in these experiments, is illustrated in Fig. 2.

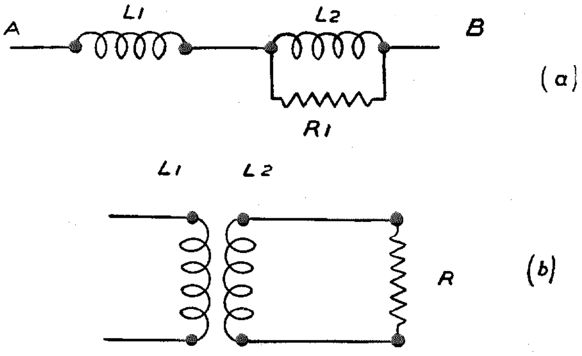


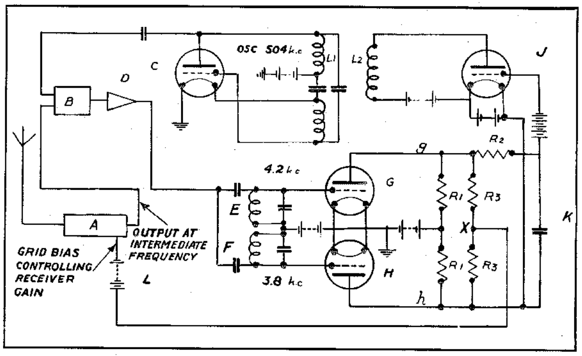
Figure 2

In 2 (*a*) a small inductance, shunted by a resistance, is connected in series with another inductance. It is clear by referring to Appendix II that the total effective inductance of the combination between points A and B depends on the value of the resistance. The same result applies, of course, to the circuit of 2 (*b*), except when the coupling between L-1 and L-2 is unity. When L-1 is the tuning inductance of a triode oscillator, the frequency of this oscillator will depend on the value of R. The resistance R may now be replaced by the plate-filament resistance of a second triode, in which case the oscillator frequency may, in general, be varied by changing the grid volts of the triode. It is this latter method that has been found the most convenient in practice in the experiments here described. A control triode of low plate resistance (about 2,000 ohms) is employed, and using a mean frequency of 500 kilocycles, a change of plus or minus 5% can easily be obtained.

The next question arising is how much frequency change is required. The answer to this depends, of course, on the degree of stability over fairly long periods of time (*e.g.*, 3 or 4 hours) of the transmitted frequency, and the average frequency of the receiving oscillator itself. If a quartz crystal be used to stabilise the first beating oscillator of the receiver (assumed to be of the superheterodyne type), and taking a reasonably good transmitter, experience has shown that a range of about plus or minus 3 kilocycles is sufficient to take into account the worst case. If the intermediate frequency in the receiver (or the first intermediate frequency in the case of more than two detectors) be taken as 500 kilocycles, this gives a necessary range for the oscillator variation of plus or minus 0.6 per cent. It is clear, then, that the control method explained above gives a range which more than amply fulfils the requirements.

Details of Systems Adopted

The frequency changing triode referred to above must now be controlled by the frequency of the pilot signal. The method of control, of course, depends on whether exact or approximate synchronisation is required. In these experiments the approximate case only has so far been attempted, and the circuit used for this is shown in its simplest form in Fig. 3. "A" represents the high frequency amplifier, first beating oscillator, first detector and first intermediate amplifier of the receiving set.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OUTPUT AT INTERMEDIATE FREQUENCY
GRID BIAS CONTROLLING RECEIVER GAIN

Figure 3

The resulting output at 500 kilocycles is applied to the rectifier B in combination with a little of the output of the synchronised oscillator C at which the average frequency is set (504 kilocycles); the output of rectifier B is passed through the low frequency amplifier D which has a resonance point at 4 kilocycles. The output of D is coupled loosely and equally to the two circuits E and F, tuning to 4.2 and 3.8 kilocycles respectively. The latter tuned circuits are connected as shown to the grids of the balanced rectifier system GH. The resonance curves of E and F are adjusted so that at exactly 4 kilocycles the losses due to the two circuits are equal and at a value of about 8 db. greater than the losses at the resonance points. If, then, the frequency of C is exactly 504 kilocycles, equal voltages will be applied to the grids of E and F, thus giving zero potential difference between the two plates of G and H.

When C differs from the incoming pilot by exactly 4 kilocycles, the potential difference between the plates of G and H is applied between the grid and filament of the control tube J, the plate coil of which is coupled to the resonant circuit of C. Assume now that for some reason the beat note between C and the pilot signal becomes slightly greater than 4 kilocycles; the plate current of rectifier G will now exceed that of H, thus increasing the negative grid bias on tube J, raising its plate resistance and hence lowering slightly the frequency of C—by this means tending to restore the beat note between C and the pilot to its original value of 4 kilocycles.

The essential principle of the synchronising action will now be evident; in practice it has been found easily possible by means of this circuit to cause the oscillator C to follow variations of the pilot signal amounting to plus or minus 5 kilocycles, the resulting beat note never differing by more than 20 cycles from the normal value of 4 kilocycles. Figure 3 also explains how the time constant is introduced into the frequency control circuit. The resistance R-2 is of the order of 5 megohms, and condenser K about 20 microfarads, giving a time constant of 100 seconds between impulsive voltage fluctuations across G H and the grid-filament of J.

Let us now consider another feature, shown in Fig. 3, which has been found essential to the successful operation of the system. It is, of course, impossible in practice for the characteristics of tubes G and H to be exactly similar; in other words, if the plate currents are exactly equal for one particular case in which the voltages across E and F are equal and at a certain level, the outputs of the rectifier tubes will not balance exactly when the voltage level on the grids is altered, although these two voltages may still be equal. Further, if exactly similar tube characteristics were obtainable, the exact balance condition between the two plate currents could never be used in practice. Some voltage difference is always necessary between *g* and *h* in order to give the desired frequency change on oscillator C.

If now the frequency remains unchanged, but the level of the pilot signal is changed, as occurs during fading, the potential difference between *g* and *h* will be changed correspondingly, with the resulting tendency to change the frequency of C; *i.e.*, the frequency of C will depend to some extent, not only on the frequency of the pilot signal, but also on its amplitude, a quite undesirable effect. To overcome this difficulty, due to the above two causes, an automatic gain control has been added. It is only necessary for a potential difference corresponding to the amplitude of the pilot signal (and not its frequency) to be used to control inversely the gain of the receiver in such a way that a very small change in this potential difference makes a considerable change in gain.

To achieve this result in the circuit of Fig. 3 the resistance R-3 is added, and the potential of the mid point X will be the average between that of *g* and that of *h*. When the beat is in the region of 4,000 cycles, therefore, at which point *g* and *h* change inversely and almost equally with frequency change, the voltage of X will depend almost entirely on the amplitude of the pilot and not on its frequency. X is connected to the battery L, which is used to counterbalance more or less the anode voltage of the rectifier tubes, thus providing a suitable controlling grid bias for one or more tubes of the receiver.

The gain control circuit is in fact very similar to that used to counteract the effects of fading in the normal double side-band type of receiver used by the I.T. & T. Corporation for short-wave work. By this means, when the pilot signal changes from a value only just above the noise level up to a level of 60 db. above this point, the 4 kilocycle volts applied to the grids E and F only change by about 10 per cent. The time constant of this automatic gain control circuit is made short enough to follow the most rapid type of fading met with in practice (neglecting, of course, the very rapid fading of more than twenty periods per second which sometimes occurs, but which is usually small in extent): a suitable value for this time constant has been found to be about one-twentieth of a second.

It is now evident that it is only when the pilot falls below the noise level that continuous control of the local oscillator is lacking. Taking the case when the pilot signal is reduced at the transmitter by 20 db. below the peak value of the side-band, and when conditions are such that the resulting signal-to-noise voltage ratio of the speech is of the order of 3 (a minimum value for a commercial circuit), the pilot at the receiver has rarely been found in practice to fall below the noise level for longer than one-tenth of a second, and as far as is known never longer than half a second. These figures, of course, are based only on results between Madrid and Paris covering a period of about five months and using a particular wave length (52 metres) with particular antenna systems at each end. It is thus difficult to say that the figures apply generally; this remains to be seen. The time constant of the frequency control circuit, made up of resistance R-2 and condenser K is sufficient to maintain the frequency of oscillator C well within the required limits during this worst case of fading lasting half a second.

Design of Complete Receiver

Having achieved sufficiently accurate synchronisation, the next question is the design of the receiver. It is clear that an ideal single side-band receiver should take account of the accurate frequency control available to reduce the band width passed by the speech circuits to the theoretical minimum of about 3 kilocycles. This can be done most conveniently by using the triple detection type of receiver, the first intermediate frequency being of the order of, say, 500 kilocycles, and the second intermediate frequency in the region of 50 kilocycles.

The first beating oscillator is controlled by a crystal, the second oscillator being controlled automatically by the pilot signal in such a way that the resultant second intermediate frequency never varies by more than 20 cycles. The band filters at 500 kilocycles have a margin of plus or minus about 4 kilocycles in addition to the width of the side-band plus pilot, thus giving a total band width of about 12 kilocycles; the final and high degree of selectivity is obtained by a band filter at the second intermediate frequency (50 kilocycles).

As the side-band frequencies at this stage have been properly stabilised, this second band filter can be accurately adjusted to cut off at exactly the points required to pass the side-band only. The receiver actually used in the tests described here is of such a design that the second intermediate frequency is, however, in the region of 20 kilocycles rather than 50, merely because 20 kilocycle apparatus was immediately available.

The next consideration in designing the complete receiver is the question of eliminating, so far as possible, the fading of the output speech. As has been remarked before, short wave fading may be divided roughly into two classes: synchronous and selective. During selective fading, in general, the average level throughout the whole side-band does not change considerably, and the gain of the receiver should, therefore, remain constant. When, on the other hand, synchronous fading appears, it is necessary to change the gain of the receiver inversely and, automatically to compensate for this.

Almost certainly the best method would be to use two or more pilot signals, *e.g.*, one placed on each side of the side-band. The average level of these two pilots will then give a good idea of the average level in the side-band itself, and, therefore, of the amount of synchronous fading present.

The frequency spacing of the two pilots may be so chosen that selective fading will not, in general, change their average very appreciably. If this latter average level were then used to control inversely the gain of the receiver used for the speech, it seems probable that the average speech output would remain substantially constant in most cases. This method, however, has not yet been tried out in the comparisons referred to. Another line of attack is based on the fact that, in general, selective fading is of short, and synchronous fading of longer, duration. If two separate automatic gain controls are used, one of very short time constant for the pilot channel only, as explained above, and the other of a time constant of the order of 30 seconds or more for the speech and the pilot channel, a fairly smooth speech level is found to result.

This type of smoothing is not perfect, however, as the assumption that the synchronous and selective types of fading have different time periods, is by no means always true. The outline of the complete circuit used is shown in Fig. 4. The constants are not, in every case, of the optimum values, but were determined by the apparatus that was immediately available.

The pilot signal used corresponds to a speech frequency of 3.47 kc. The reasons for this position of the pilot are two-fold:

(1) The maximum speech energy lies in the low frequency range below 500 cycles; it is, therefore, advisable to space the pilot as far as possible from these regions of maximum energy. In order to avoid an appreciable increase of band width, however, a distance of more than 400 or 500 cycles from one end of the side-band should not be exceeded.

(2) The audio output obtained in an ordinary receiver when listening to such a transmitter will give speech that is inverted and displaced by 400 cycles. Such an output is practically unintelligible, thus rendering the system private, although, of course, not secret, as an oscillating detector adjusted accurately at the correct frequency will always give straight speech. This latter objection, of course, also applies to any simple form of privacy system depending on inversion or displacement.

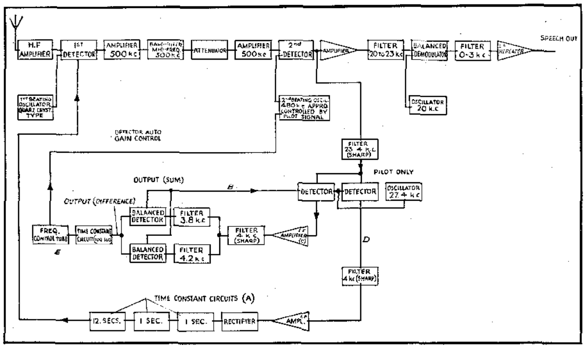

Figure 4

The pilot is normally at a level 20 db. below the overloading point of the transmitter. Owing to the very small band width used in the receiver for selecting the pilot, the resulting signal-to-noise ratio due to the pilot is about the same as that of the speech side-band, which is 10 or more decibels higher in level. It is thus easily sufficient to carry out any desired synchronising or gain-control processes. The necessary reduction of the peak value of the side-band to avoid overloading due to the presence of the pilot is very small (of the order of 0.1 db.) so that practically the full gain of the single side-band system is realised.

The automatic gain controls are similar to those already in commercial use in short-wave receivers developed by the Bell Laboratories and the International Telephone and Telegraph Corporation. The action consists simply of a rapid increase in grid bias voltage on a detector or amplifier in the earlier stage of the receiver whenever the D.C. output of the final detector to be controlled exceeds a predetermined limit. Such a change in grid bias reduces the gain of the tube in question until the final level is again at the correct value. In each case, between the output detector and the tube of which the gain is being controlled, there is inserted a time constant circuit of a value suitable to the particular function desired. The circuits A shown in Fig. 4 are built up in three sections in order to give a correct curve of output voltage against time, which is more suitable than can be obtained with a single section. The gains of the various detectors and amplifiers are adjusted so that the chief component of background noise in the final speech output is due to the grid circuit of the first high frequency amplifier; and the antenna is such that, except under unusual circumstances, the chief component of this first grid noise is caused by static. The same remark applies to the circuit of the pilot channel. The gains are such that, when no signal is being received, the static under conditions of minimum strength is beginning to affect the frequency control tube and also the two automatic gain controls. It is of no advantage to increase the gain beyond these limits, and it is evident also that this arrangement gives the best possible signal-to-noise ratio obtainable with the particular antenna used and under the given transmission conditions.

Synchronisation Limits

Even when receiving signals giving a final speech-to-noise ratio less than that required for a commercial circuit, but good enough for passing service messages, and even when the worst fading met with in practice is present, the pilot may still be kept 20 db. below the peak of the side-band, and the first intermediate frequency (500 kc. range) may change by about ± 5 kc. without changing the second intermediate frequency by more than 20 cycles. This limit clearly gives an ample margin. The transmitter frequency rarely changes by more than 1 kc. from its normal value, and a change of 2 kc. in the crystal beating oscillator is rare even when an accurate thermostat is not used.

The only other variable factor is the natural frequency of the 480 kc. oscillator when uncontrolled. This can easily be kept within one part in a thousand of its normal value, *i.e.*, 500 cycles. It is very desirable that the first beating oscillator be of a quartz crystal type, firstly to keep its slow frequency drift within the required limits, and secondly to avoid changes of frequency due to a change in signal strength when the latter is at a high level. On account, chiefly, of the action of the automatic gain control on the first detector, to which the beating oscillator is coupled, a change in frequency of the latter is, in general, caused by variations in the received signal, unless special care is taken to avoid this. The use of a crystal oscillator is not a serious objection, as a commercial receiver is not generally used for more than about three wavelengths.

Single Side-Band Transmitter

The block schematic of the transmitter used in these experiments is shown in Fig. 5. The problem was to evolve a transmitter design giving distortionless single side-band speech with sufficient stability but using, as far as possible, the existing double side-band equipment. The method of solving the problem may perhaps be of interest for illustrating the extreme flexibility of the low power modulation type of transmitter; it will be seen that the change-over from double to single side-band working can be carried out comparatively simply and rapidly.

The single side-band is obtained by modulation in three successive stages. The first two are at 19 and 250 kilocycles respectively, the modulators being balanced in each case, and the side-band being selected by appropriate filters. For the final modulation the existing harmonic generator of the transmitter was employed with the negative grid bias increased to a point such that, within certain limits, the voltage in the output harmonic was linearly proportional to the grid voltage. By this means, when the side-band output of the second balanced modulator is applied to the harmonic generator grid, this latter tube gives the second harmonic and acts as a modulator at the same time.

This third modulator is not balanced, and consists of a single tube, but a sufficient suppression of the carrier and the unwanted side-band is obtained by increasing the selectivity of the rest of the transmitter by sharply tuned circuits.

This type of transmitter circuit has been found to work quite well in practice.

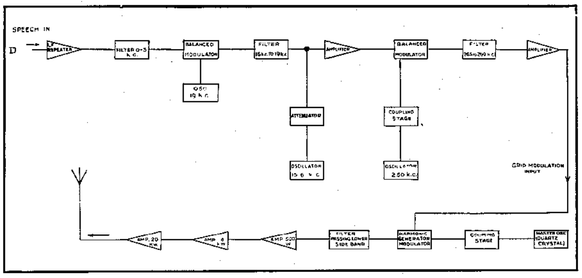

Figure 5

Tests Carried Out

During the period from April, 1930, to March, 1931, single side-band tests have been carried out by the International Telephone and Telegraph Corporation over the following three links:

(a) Buenos Aires to Madrid.
(b) Local tests at Madrid (Pozuelo to Griñon, 80 kilometres).
(c) Madrid-Paris.

As no single side-band transmitter had been installed at Buenos Aires, the tests on this link have consisted, so far, chiefly of experiments to check the automatic synchronising device, using the carrier of the ordinary double side-band transmitter as the pilot signal. The wavelength used was 15 metres.

During the second series of tests, viz., those between Pozuelo and Griñon, the complete system was tried out, using the provisional transmitter that has just been described. Although the distance was only 80 kilometres (between the Madrid transmitting and receiving stations of the Madrid-Buenos Aires link) the conditions were artificially made more or less similar to those prevailing on a commercial link by using directive antennae at both transmitter and receiver pointing in the wrong directions; by this means, the field strength and fading were found to be approximately those of the commercial Madrid-Buenos Aires link. For these local tests, a 30 metre wavelength was employed.

The final series of tests between Madrid and Paris, extending from November, 1930, to March, 1931, used the same transmitter as in the local Madrid experiments, but on wavelengths of the order of 30 to 52 metres. In each case the choice of wavelength was influenced solely by the transmission path conditions during the hours when experiments were possible. Owing to the exigencies of traffic, these hours were limited almost entirely to the period from 10 P.M. to 10 A.M.

Results of Tests

Buenos Aires to Madrid.—These tests, carried out with a receiver not yet in its final form, gave a maximum frequency difference between transmitted and re-supplied carrier frequencies of about 20 cycles per second, except during unusually heavy fading periods. No attempt was made to reduce the strength of the carrier below the normal value. These results were thought sufficiently promising, and showed that the system had good future prospects. On the other hand, the fact that adequate synchronisation could not quite always be obtained on account of severe fading, showed the necessity of some improved device to compensate for these severe fading periods.

Local Tests at Madrid.—Before the start of the second series of tests locally between Pozuelo and Griñon, the following two improvements were made:

1. The first beating oscillator of the receiver was converted to the quartz crystal type as shown in Fig. 4.
2. The automatic gain control B (Fig. 4) on the frequency control branch of the pilot circuit was improved by increasing the gain of the amplifier C so that any level of pilot signal between the measurement found in these local tests and the value only just above the noise would effect the frequency control tube equally. The output branch D of the pilot channel controlling the gain of the whole receiver through a comparatively long time constant had not yet been installed.

Test 1: Synchronism.—No long period stability tests of the synchronising device were attempted during these preliminary tests, but for periods of half an hour's duration a difference of 20 cycles per second between transmitter and receiver carriers was rarely exceeded.

Test 2: Speech Quality.—Except during the few occasions when the synchronism was not good enough, the speech quality was found to be quite satisfactory; in fact, during selective fading conditions, as had been foreseen, the quality was better than that given by the normal double side-band system.

Test 3: Improvement in Signal-to-noise Ratio.—This ratio was measured, both in the double and single side-band cases, at the final low frequency output by a standard volume indicator. As signal, a tone of 1,000 cycles was employed. Complete fades are, of course, frequently obtained in both the single and double side-band cases, so that exact measurement was difficult. An average value had to be estimated in each case, and the means of a number of observations taken. A further difficulty was the fact that, although the system was changed from double to single side-band, and vice-versa, as quickly as possible, the transmission conditions usually altered quite appreciably during the change-over periods. The results measured in this way showed a gain of 17 db. with the same peak power in the antenna in the two systems. This figure is considerably higher than the value expected theoretically: between 9 and 12 db. The cause of the discrepancy has not been satisfactorily explained.

Inasmuch as the type of fading is necessarily different when using the two systems, it is clear that the average value will not have exactly the same meaning in one case as in the other. It may be that the explanation lies here.

It is true that if the double side-band received carrier is only just above the noise level, the total noise received in this system will very appreciably depend also on the received band width, as explained in Appendix I.

As the band width of the receiver is about 20 kc. the maximum increase of the double side-band noise over that of the single side-band case would be

$$\sqrt{\frac{20}{6}} = 1.75 \text{ approximately}$$

i.e., about 4.5 db., giving a total gain from double to single side-band of about 16 db. In the tests referred to, however, the double side-band signal-to-noise ratio was never less than about 12 db., so that it seems that this latter possible explanation cannot apply.

Test 4: Speech Quality.—This was found again to be perfectly satisfactory, and better than during double side-band working.

MADRID-PARIS TESTS

Test 1: Synchronism.—In the absence of gain control D, Fig. 4, the synchronism was not always perfect, as the range of the fading (taking the minimum as the minimum value lasting more than half a second) frequently exceeded the control range of gain control B. To overcome this trouble, and at the same time to reduce the fading of the speech output, the separate control D was introduced, as shown in Fig. 4. By this means, the total range of the fading control on the signal was increased to a point such that the correct synchronising action never ceased for periods longer than about a quarter of a second.

The time constant E, Fig. 4, was quite sufficient to keep the oscillator frequency sufficiently constant during these short periods. At the beginning of March, 1931, during the stability tests on the complete system, covering ten consecutive nights, the re-supplied carrier frequency never differed from the suppressed carrier by more than 6 cycles per second, except for two or three moments when the transmitter was accidentally shut down—a result definitely better than had been hoped for.

Test 2: Speech Quality.—The received quality in Paris was found to be always as good as that obtained from the double side-band, and very definitely better during bad selective fading conditions.

Test 3: Signal-to-noise Ratio.—In these Madrid-Paris tests an improved type of signal was used. Instead of a single tone a noise-producing buzzer was employed giving audio frequency energy more or less evenly distributed throughout the whole speech spectrum. This type of signal was thought to be a much better imitation of speech from the point of view of fading than the single tone. The average result from a number of observations showed a gain of 12 db. when compared with the double side-band receiver with the automatic gain control off, and of 13 db. compared with the same receiver with its gain control on. This is evidently equivalent to increasing the power of the transmitter slightly more than 16 times. The peak powers in the antenna were carefully adjusted to be the same in the two systems. The curve showing one night's comparisons between the double and single side-band with the ratios plotted against time is shown in Fig. 6.

Test 4: Fading.—After the extra gain control D had been added the fading on the speech output was in general definitely less than the best that could be obtained with double side-band working with automatic gain control. Improvements showed that more particularly (as, in fact, all other advantages of single side-band working during bad selective fading) the usual automatic gain control on double side-band receivers is quite incapable of dealing properly with selective fading. When the carrier fades out the gain of the receiver is usually increased very considerably, giving a loud distorted speech output.

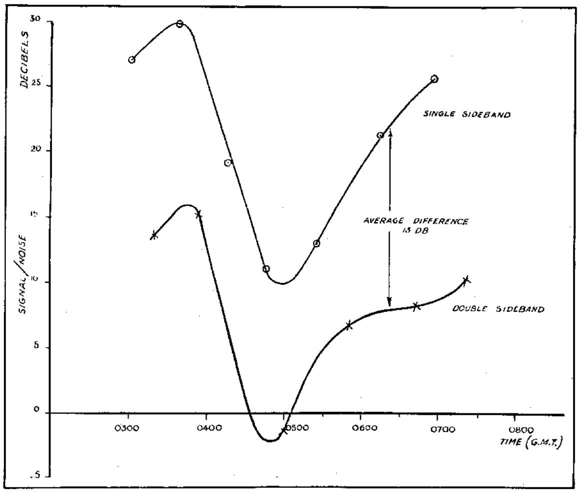

Figure 6

With the single side-band arrangements shown in Fig. 4, however, speech fading is very largely compensated for. The selective fading is usually found to be fairly rapid, so that the gain control D, working through a large time constant to the first detector of the receiver, has no time to operate. This is clearly the correct condition, as during selective fading the average power in the speech side-band is substantially constant. When synchronous fading occurs, however, it is usually of comparatively long duration, and thus operates control D, keeping the speech output fairly constant. The only way of making a really accurate comparison between two anti-fading devices is by a long series of observations over an extended period. From the results so far obtained, however, between Madrid and Paris it seems that the average fading, when using the present single side-band system, is about half that with the normal double side-band receiver, and during exceptionally bad conditions, the improvement is greater than this.

Test 5: Intelligibility—No accurate tests on the improvement of intelligibility were attempted, but on several nights rough comparisons were made by using short word lists, and changing over as rapidly as possible between the two systems. Improvement in the intelligibility was, of course, much more marked when the signal-to-noise ratio was low. One result which seems fairly clear, however, is that when the percentage intelligibility in double side-band is of the order of 20, the corresponding figure with single side-band working is usually between 70 and 80. In other words, a change from double to single side-band is capable of changing an uncommercial into a good commercial circuit.

Test 6: Stability of System.—As has been mentioned above, continuous tests, each lasting from two to three hours, were carried out on ten consecutive nights. Speech was used at regular intervals throughout all the tests, and the results showed a perfectly commercial circuit with good quality throughout the whole period, with no interruption whatever except during one or two short periods when the transmitter was shut down. It was actually unnecessary to touch the receiver at all throughout the tests, except for the preliminary tuning each night. Actually, however, when a frequency difference of 5 or 6 cycles was observed (usually once half-way through the night), the de-modulator oscillator was re-adjusted to restore the zero beat conditions.

Conclusion

The results obtained have definitely shown that one system of single side-band working, applicable commercially to short-wave links, has been evolved.

The author of this article wishes to acknowledge his indebtedness to Mr. C. W. Earp and Mr. H. T. Roberts, of the International Telephone and Telegraph Corporation, for their valuable assistance during the above experiments and the preparation of this paper.

APPENDIX I

Signal-to-Noise Ratio Improvement

In comparing the two systems let us assume equal peak voltages; and in the double side-band case, let the transmitter be modulated to 100 per cent.,

(1) DOUBLE SIDE-BAND CASE.

If the carrier is represented by

$$V \sin \omega t$$

then the peak voltage of each side-band is:

$$\frac{V}{2}$$

In the speech-producing detector of the receiver, let the audio voltage produced by beating each side-band separately with the carrier be represented by

$$\frac{KV^2}{2}$$

where K is, of course, a constant depending on the receiver, the transmitter, and the intervening circuit conditions. If now the phases of the side-bands with respect to the carrier are the same on arriving at the receiving detector as they were originally in the transmitter, the audio frequencies produced by each side-band separately with the carrier will be in phase in the detector output; the resultant is therefore

$$KV^2$$

Now let us consider the total background noise, the noise level being defined as that occurring when the incoming carrier is unmodulated. If the carrier energy in the speech detector is large compared with the noise energy picked up in the band width considered (this is always the case in "commercial" radio telephone circuits) then the only audio noise that need be considered in the output of the speech detector is that produced by noise impulses beating with the carrier. Thus the background noise voltage is:

$$KV\sqrt{\sum_{\omega-F}^{\omega+F} V^2}$$

where the noise input to the detector is

$$\sum_{\omega-F}^{\omega+F} V$$

and assuming in an ideal receiver that only frequencies from $(\omega-F)$ to $(\omega+F)$ are passed, where F is the highest audio frequency to be considered, and assuming also that the noise impulses arrive at random times. Hence the resulting signal-to-noise ratio R_1 is equal to:

$$\frac{V}{\sqrt{\sum_{\omega-F}^{\omega+F} V^2}}$$

(2) THE SINGLE SIDE-BAND CASE.

In order to give the same peak voltage at the transmitter as before, the tone which in the previous case gave 100 per cent. modulation must now be transformed into a single radio frequency of peak voltage 2V. Assume now that the peak voltage of the local oscillator re-supplying the carrier at the receiver is V_0; then the audio tone produced by the incoming side-band is $2KVV_0$ and the noise is:

$$KV_0\sqrt{\sum_{\omega-F}^{\omega+F} V^2}$$

Assuming that the receiver passes the upper side-band only in this case, then the signal-to-noise ratio R_2 will be:

$$\frac{2V}{\sqrt{\sum_{\omega}^{\omega+F} V^2}}$$

Assuming that the noise impulses are distributed evenly throughout the band width, then

$$\sum_{\omega-F}^{\omega+F} V^2$$

is double

$$\sum_{\omega}^{\omega-F} V^2 \quad \text{, so that } \frac{R_2}{R_1} = 2\sqrt{2}$$

giving thus a gain of 9 db.

In the case of short wavelengths, however, there is another fact to be considered. During fading, selective phase distortion frequency occurs in the transmission path, causing the phase of one side-band with respect to the carrier, in the double side-band case, to be more or less random as compared with the phase of the other side-band. In this case the average resultant of the two side-bands will give an audio voltage of

$$\frac{KV^2}{\sqrt{2}} \text{ rather than } KV^2.$$

R_1 is then:

$$\frac{V}{\sqrt{2\sum_{\omega-F}^{\omega+F} V^2}}$$

giving an improvement due to the single side-band system of 12 db. In practice a gain of 9 to 12 db is obtained, according to the transmission conditions.

APPENDIX II

Variable Reactance Circuit

Referring to Fig. 2 (*a*), we have the following expression for the impedance (R+jX) between points A and B:—

$$R+jX = R_1\frac{\omega^2L_2^2}{R_1^2+\omega^2L_2^2} + j\left(L_1+L_2\frac{R_1^2}{R_1^2+\omega^2L_2^2}\right)$$

Micro-ray Radio

ULTRA short wave radio telephony and telegraphy, known as Micro-ray Radio, was demonstrated successfully between Dover and Calais on March 31st by the International Telephone and Telegraph Laboratories, Inc., of Hendon, England, in cooperation with the laboratories of Le Materiel Telephonique, of Paris, France. The equipment was largely developed by French engineers in the Paris laboratories.

The Micro-ray System employs transmitting and receiving antennae only 2 cm. in length. It has a wave length as low as 18 cm. and requires power of only one-half a watt. Micro waves are not subject to fading such as is encountered with other waves nor are they absorbed by rain or fog as are light waves. The conversations exchanged between Dover and Calais were of high quality and well up to the standard of the best telephone transmission.

The Micro-ray System opens up a veritable no man's land of additional radio accommodations since it makes available nearly one-quarter of a million Micro-ray channels even if each transmitter differs in wavelength to the same degree as is now necessary with ordinary transmitters. Furthermore, if it were physically possible to group such a vast number of stations together in the same locality they would still work perfectly without interference.

Apart from their obvious applications in a world-wide communication network such as that of the International System, a ray which is not affected by weather conditions such as fog and rain will very greatly extend the usefulness of lighthouses, especially at times when they are now least effective and are most needed due to poor visibility. For maintaining secret communication between aircraft and land and between ships of a fleet at sea, the Micro-ray offers fruitful possibilities. Other valuable applications will be the landing of aircraft in darkness or fog and dependable means for ships to locate each other in foggy weather. In the field of television also the Micro-ray should permit developments which are not practicable with the wave lengths hitherto available.

The *Electrical Review*,[1] under the caption "Short-wave Radio Telephony," in connection with the Micro-ray commented editorially:

"One of the major problems of radio communication today is the crowded condition of the ether. Indeed, the bogey of congestion is so menacing that serious attempts are being made internationally to evolve some workable scheme of virtually rationing frequencies, whilst it has also provided the impetus to explore the possibilities of the shorter wavelengths. The use of the 5- to 50-metre range is satisfactory for long-distance commercial communication, but, while the directive properties of short waves tend to simplify the avoidance of mutual interference, practical difficulties of application unfortunately increase progressively with increase of frequency. So acute did the situation become as to induce investigation even within the range of three metres, below which known technique does not appear to have been attended with any substantial degree of success. What was seemingly needed was some radical change in method, and it was an advance of that magnitude which was demonstrated successfully last week. . . . . . . as the culmination of work commenced about a year ago in a new field—so different from the existing one as to justify another name. Subject to entirely different conditions and necessitating a technique of its own, the extreme simplicity of the equipment and its ridiculously small power requirements mark a new epoch in the art of electrical communication."

For a description of the Micro-ray the reader is referred to *The Electrician* (issue of April 3, 1931, Volume CVI, No. 2757). It also contains an interesting editorial under the heading, "10-100 cm. Radio."

A distinguished group of officials of the British Government and Military and Naval Attachés from various countries, leading scientists, and representatives of the press attended a demonstration at Dover while a similar group of French

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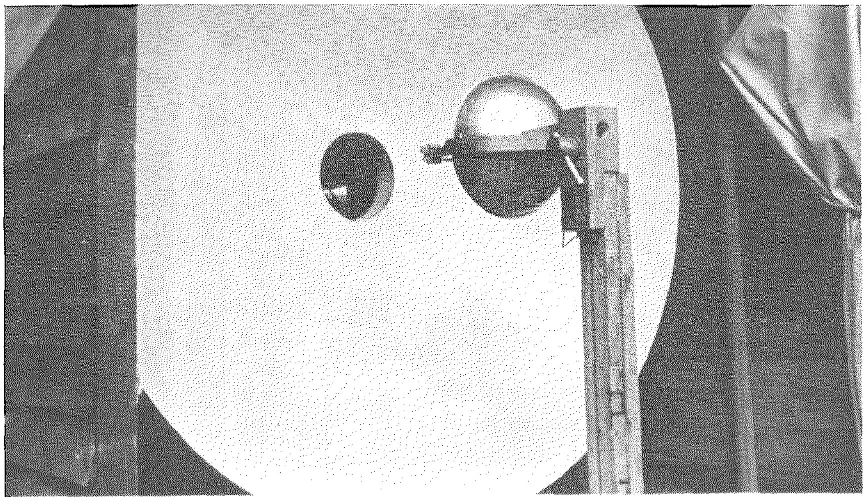
[1] April 10, 1931, issue.

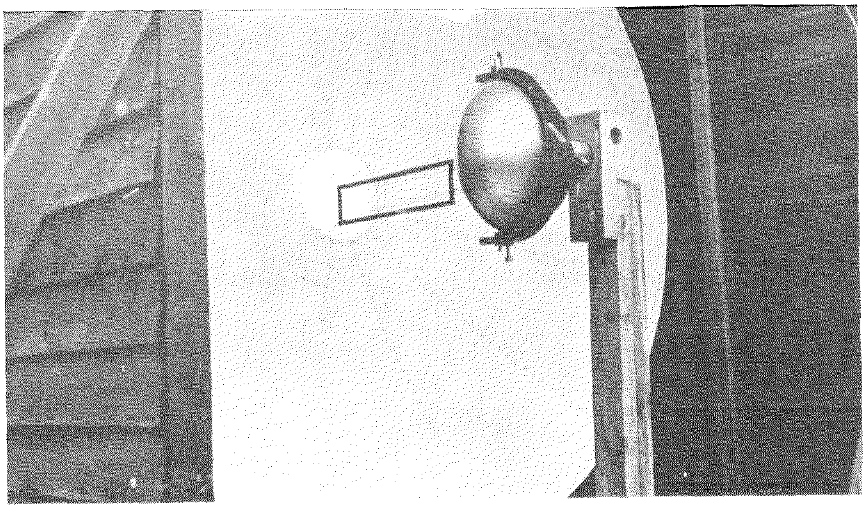
Government officials and guests came from Paris to Calais to participate in the demonstration. Later there was a luncheon in England at the Lord Warden Hotel where Mr. G. H. Nash, Executive Vice President of the International Telephone and Telegraph Laboratories, lectured on the Micro-ray System. In France there was a similar lecture by Mr. E. M. Deloraine of Le Matériel Téléphonique.

In addition to Messrs. Nash and Deloraine, credit for the new system is largely due to Messrs. Clavier, Darbord, Fournier, and Gibson.

The Transmitter



The Receiver



The large transmitting and receiving reflectors are 10 feet in diameter. Identical apparatus is used at each end.

The Practical Value of the Proximity Loss in Parallel Go and Return Conductors

By J. K. WEBB, M.Sc., A.M.I.E.E.

International Telephone and Telegraph Laboratories, Incorporated

IN the case of a cylindrical conductor isolated in space, or two concentric conductors carrying alternating current, there is a concentration of current towards the outer surface of the conductor, and the problem of calculating the increment of resistance due to this non-uniformity permits of a rigid mathematical treatment, there being general agreement as to its solution.[1] This will be referred to as the "simple skin effect." When, however, a circuit is formed by two parallel conductors, there is a further re-distribution of current due to mutual repulsion between the two magnetic fields, a phenomenon which is termed the "proximity effect."

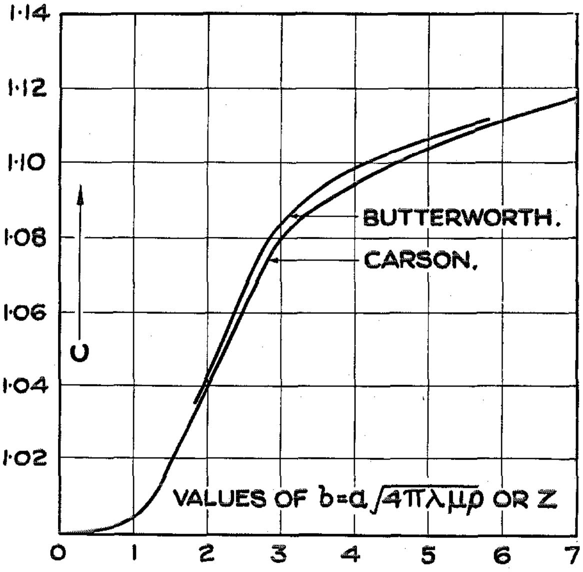


Figure 1—Comparative Values of Correction Factor "C" Calculated from Carson's and Butterworth's Formulae.

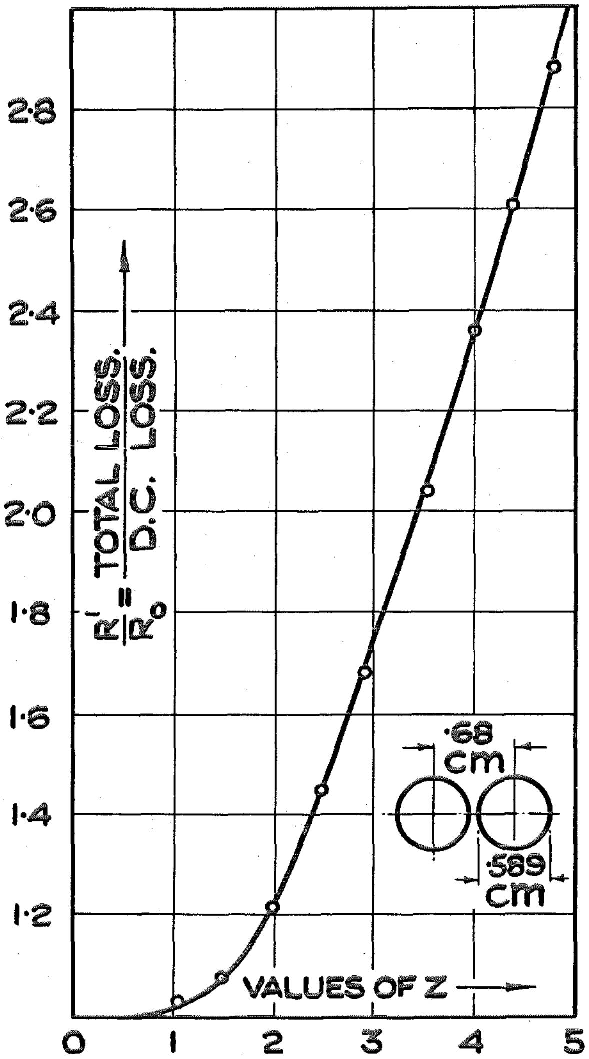


Figure 2—Curve of Total Loss Calculated by Butterworth's Formula Showing Observed Points.

While the increment of resistance due to this effect is considerably less than that due to the simple skin effect alone, it is by no means negligible in large gauge wire at audio frequencies, or in smaller gauge wire at the higher frequencies used in carrier communication. Due allowance, therefore, must be made when considering the design of circuits for such uses.

To this end it is convenient to have a formula which can readily be applied to specific cases; but, since the mathematics of the problem present difficulties which make a perfectly rigid solution unduly cumbersome for engineering application, the limits of error which may be introduced due to making simplifying assumptions must be carefully considered before the formula can be applied with confidence.

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[1] Russell, "Alternating Currents," Vol. 1, Sec. Ed., P. 215.

There are two important contributions towards the solution of the problem, the first by Carson,[2] and the second by Butterworth,[3] and a study of these papers shows that while Butterworth's formula is the simpler, Carson's analysis is perhaps the more rigid, but his formula involves considerable labour in its practical evaluation. It is therefore desirable to come to some understanding concerning the extent of the approximation to be expected from one or the other formula, and this can best be done by taking some specific case, calculating the value of the proximity loss by each method, and then comparing measured and calculated results.

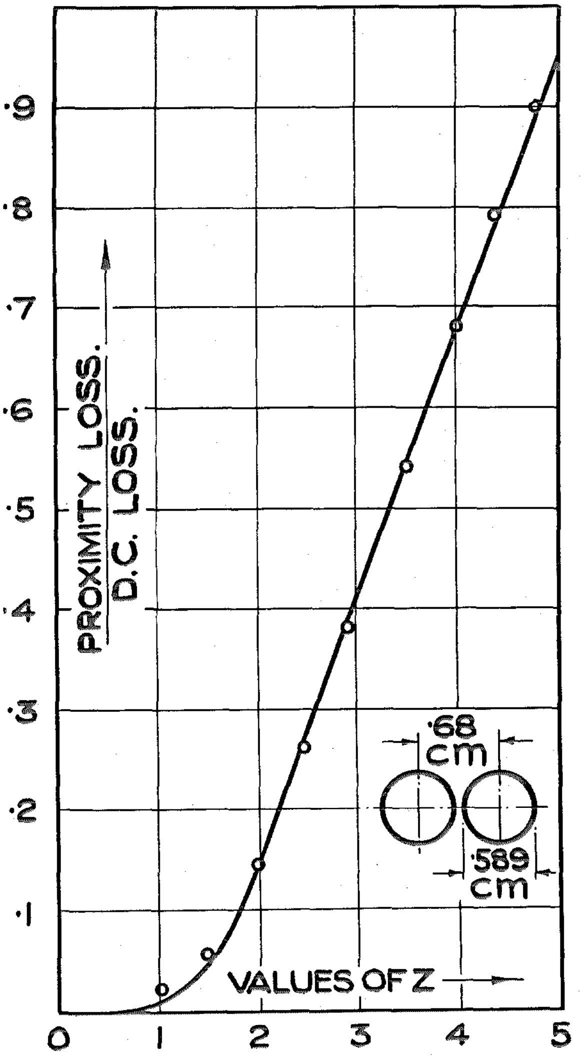

Figure 3—Curve of Proximity Loss Calculated by Butterworth's Formula Showing Observed Points.

Carson expresses the proximity loss as a "correction factor" C, which when multiplied by the effective resistance of the wire including the simple skin effect, gives the total resistance. This factor C approaches an upper limit C_m at infinite frequency in accordance with an asymptotic formula. Butterworth, on the other hand, gives the total effective resistance in the following terms:

$$R' = R_o \left\{ 1 + F_{(Z)} + \frac{G_{(Z)}}{1 - \frac{d^2}{D^2} H_{(Z)}} \cdot \frac{d^2}{D^2} \right\}$$

where R_o = D.C. resistance/cm. of single conductor in c.g.s. units.

$R_o(F_Z)$ = Increment of resistance due to simple skin effect.

d = diameter of either wire.

D = distance of their centres.

$Z = 2\sqrt{\omega / R_o}$

$\omega = 2\pi$x frequency.

$F_{(Z)}$, $G_{(Z)}$, $H_{(Z)}$ are implicit ber and bei functions which have been tabulated as follows:

Z	$F_{(z)}$	$G_{(z)}$	$H_{(z)}$
0.0	0.000	0.000	0.0417
0.5	0.000326	0.000975	0.042
1.0	0.00519	0.01519	0.053
1.5	0.0258	0.0691	0.092
2.0	0.0782	0.1724	0.169
2.5	0.1756	0.295	0.263
3.0	0.318	0.405	0.348
3.5	0.492	0.499	0.416
4.0	0.678	0.584	0.466
4.5	0.862	0.669	0.503
5.0	1.042	0.755	0.530

The function $(1+F_{(Z)})$ is also tabulated by Russell[4] for smaller increments of Z.

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[2] "Wave Propagation over Parallel Wires: The Proximity Effect," *Philosophical Magazine*, April 1921, Vol. 41, No. 244, P. 607.

[3] "Eddy Current Losses in Cylindrical Conductors with Special Application to the Alternating Current Resistance of Short Coils," N. P. L., Collected Researches, Vol. XVIII, 1924, Part VI, pp. 77-122.

[4] Ibid I, p. 233.

The last term of the formula takes account of the proximity loss.

On page 632, Figure 7 of Carson's paper, the correction factor C has been evaluated for the important practical case in which the separation of the wires is twice their diameter so that a comparison can be effected by calculating this curve from Butterworth's formula, which gives as the equivalent of Carson's correction factor

$$C=1+\left(\frac{G_{(Z)}}{1-\frac{d^2}{D^2}H_{(Z)}}\ \frac{d^2}{D^2}\right)\Big/\ (1+F_{(Z)})$$

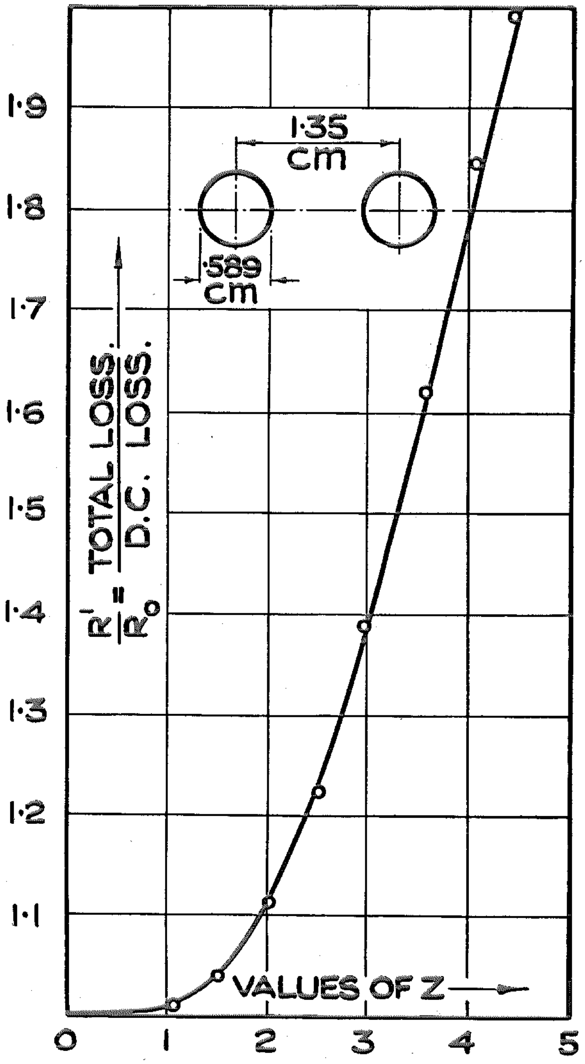

Figure 4—Curve of Total Loss Calculated by Butterworth's Formula Showing Observed Points.

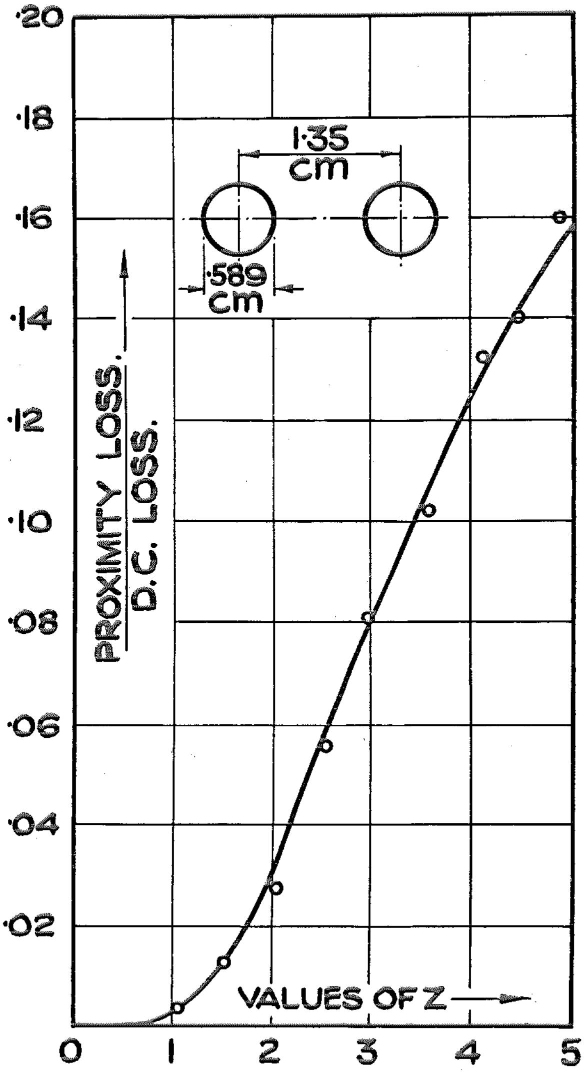

Figure 5—Curve of Proximity Loss Calculated by Butterworth's Formula Showing Observed Points.

It must also be noted that the argument Z of Butterworth's formula is the same as $b=\sqrt{4\pi\lambda\mu p}$ of Carson's, and that the practical range of frequencies and conductor sizes involves in general values of the argument up to about 5. The curves calculated from the two formulae have been reproduced in Figure 1 from which it is seen that they are practically coincident.

Results of Practical Tests

Experimental work was undertaken to determine how closely the measured and calculated values of the proximity loss were in agreement. The A.C. and D.C. resistance of a length of 3260 cm. bare copper wire of diameter 0.232″ (.589 cm.) arranged as a loop was determined at various frequencies ranging from 280 to 6000 p.p.s. by means of a special type of inductance bridge which has been developed in the Laboratories for measurements of this type.

The wire was mechanically stretched to remove kinks and accurately spaced, the ends being securely soldered to a mercury short-circuiting key, used in obtaining bridge zeros, the method of test being essentially one of double balance. Measurements were made at two spacings, the first with the wires as close together as practicable and the second at a normal distance. This particular section of conductor for example might be used on a long distance submarine telephone cable. The D.C. resistance of the loop was .0210 ohm on an average at room temperature, i.e., 6450 abohms/cm. Experimental points are shown in Figures 2, 3, 4 and 5, together with curves calculated from Butterworth's formula. In Figures 3 and 5, the points shown were obtained by subtracting from the total incremental loss the calculated value of the simple skin effect, the remainder being taken as the measured proximity loss. The deviation of the measured from the calculated values shown in Figure 5, it should be noted, is within the limits of the accuracy with which measurements could be taken, since bridge readings only to the nearest .0001 ohm could be obtained.

Conclusion

The general conclusion is that while either Carson's or Butterworth's formula may be safely used for the practical evaluation of the loss due to proximity effect in parallel conductors, the latter is preferred by the author on account of the greater ease with which it may be applied to specific cases.

Public Service of Phototelegraphy in Japan

By SANNOSUKE INADA

Director General of Telegraph and Telephone Engineering
Department of Communications, Japan

IN spite of the comparatively short time that phototelegraphy has been in practical use, it has already proved of vast importance for communication purposes.

In July, 1928, the Department of Communications of the Imperial Japanese Government issued a Departmental Ordinance, permitting the granting of licenses for the operation of private phototelegraph equipment to newspapers, on the condition that such equipment be used for the transmitting of newspaper publications. Upon the occasion of the Imperial Coronation of that year, the Osaka Mai-Nichi (Daily News), the Asahi (The Rising Sun) and the Nippon Dempo Tsushin-Sha (Telegraph News Agency) took advantage of this ordinance and equipped phototelegraph installations on their private lines. These installations were effectively utilized, with the result that the scenes of the Grand Coronation were transmitted to distant places with the least possible delay and were distributed by means of "Extras" to the public, who received the pictures with great excitement.

Shortly after this, our Department decided to open a public phototelegraph service between Tokyo and Osaka, adopting the N. E. system. The installation in both central telegraph offices and also in the Nagoya repeating station was finished in April, 1930. On the 20th of August, the inauguration of this service took place in the presence of notabilities, customers, and experts who were assembled at the two terminal offices. The ceremony was commenced by the passing of congratulations by Mr. Koizumi, the Minister of Communications, to Mr. H. Seki, the Mayor of Osaka, and this was immediately followed by a cordial reply and many other messages from the gentlemen present. All of the pictures and manuscripts transmitted during this occasion were received with excellent results and were handed over to the addressees. Since then the public service has been carried on with satisfaction.

The N. E. system was invented by Dr. Y. Niwa and Mr. M. Kobayashi, of the Nippon Electric Company, Limited, and a detailed description by Dr. Niwa* has been published. Subsequently, some improvements have been made and consequently a brief description of the equipments actually installed may be of interest.

Systems Employed

Actually two types of phototelegraph apparatus were installed for service between Tokyo and Osaka. One of these was designed to operate, at high speed, over the open-wire telephone wire, while the other was intended for operation on the 4-wire repeatered cable circuit and for use in case of interruption of the open-wire line. The former was called No. 1 Set and the latter No. 2 Set, and in the following description the mechanism and operation of the two types are common except where particularly indicated.

Sending Apparatus

At the sending terminal a pulsating light flux is produced by interrupting with a rotating toothed wheel the light emanating from the source, as shown in Figures 1 and 2. The picture to be transmitted is mounted on a drum in such a way that the pulsating light flux is projected on it.

The light is reflected from the picture onto a photocell and causes a picture current to be transmitted. After the picture current is amplified, there is sent out on the line a carrier current modulated in accordance with the respective brightness of the original and with the lower half of the frequency band eliminated by means of a high pass filter. The frequency of the carrier current is about 6000 cycles per second for No. 1 Set and about 1700 cycles for No. 2 Set.

With this equipment it is possible to transmit photographs, manuscripts, certificates, etc., in

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*Y. Niwa, "A System of Electrical Transmission of Pictures," *Electrical Communication*, April, 1930.

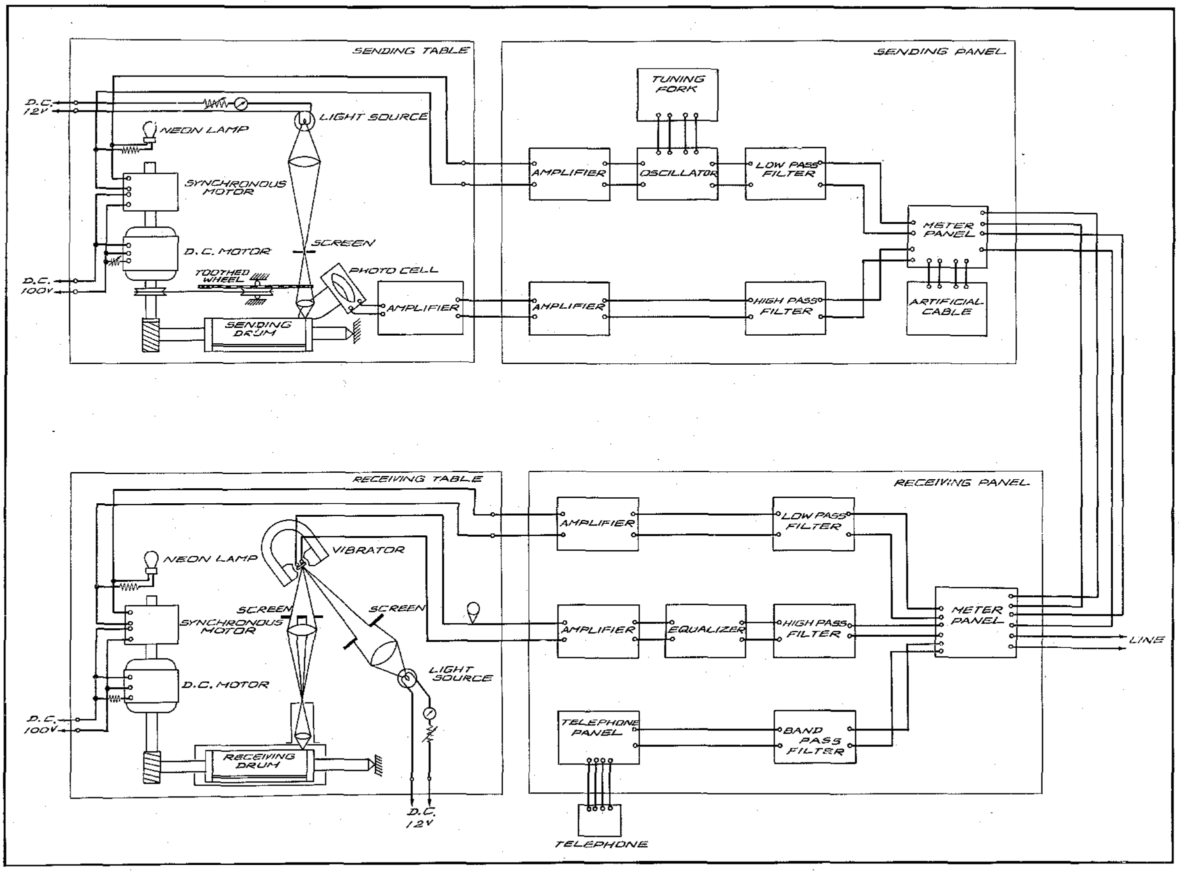


Figure 1—Schematic Diagram of No. 1 Phototelegraph Apparatus.

suitable size without being subjected to any special preparation beforehand; the largest size of the picture that can be transmitted is double that of cabinet size, that is, 18 x 26 cm.

If a picture is transmitted from a negative film by a transmitted light, higher efficiency of the light utilization may be obtained, but for simplicity and convenience the equipment was designed to be adaptable to reflected light.

The pitch of the scanning spiral is 6 lines per mm. and the time required for the transmission of the full size of 18 x 26 cm. is about 6 minutes with No. 1 Set and about 20 minutes with No. 2 Set.

Receiving Apparatus

A 50-watt incandescent lamp is used as the light source from which light flux is projected upon the reflecting mirror of the vibrator. If a part of the vibrating light flux is cut off by a screen, a definite relation is established between the intensity of the remaining light and the amplitude of vibration of the mirror. Now if this remaining light is collected by lenses and projected upon the film or printing paper mounted on the receiving drum, a spot of light, corresponding to the amplitude of the carrier waves received, is produced upon the sensitized film or paper. As the receiving drum operates in synchronism with the sending drum, the picture at the sending station can be completely received. (Figures 1 and 3.)

In the case of receiving a picture in negative film, a screen consisting of two square openings (Figure 4–N) is employed; then the light spot reflected from the mirror is intercepted by the center of the screen, as shown by the shaded portion in Figure 4–1, when no current is flowing in the vibrator. If, however, a carrier current flows in the vibrator, the reflected light

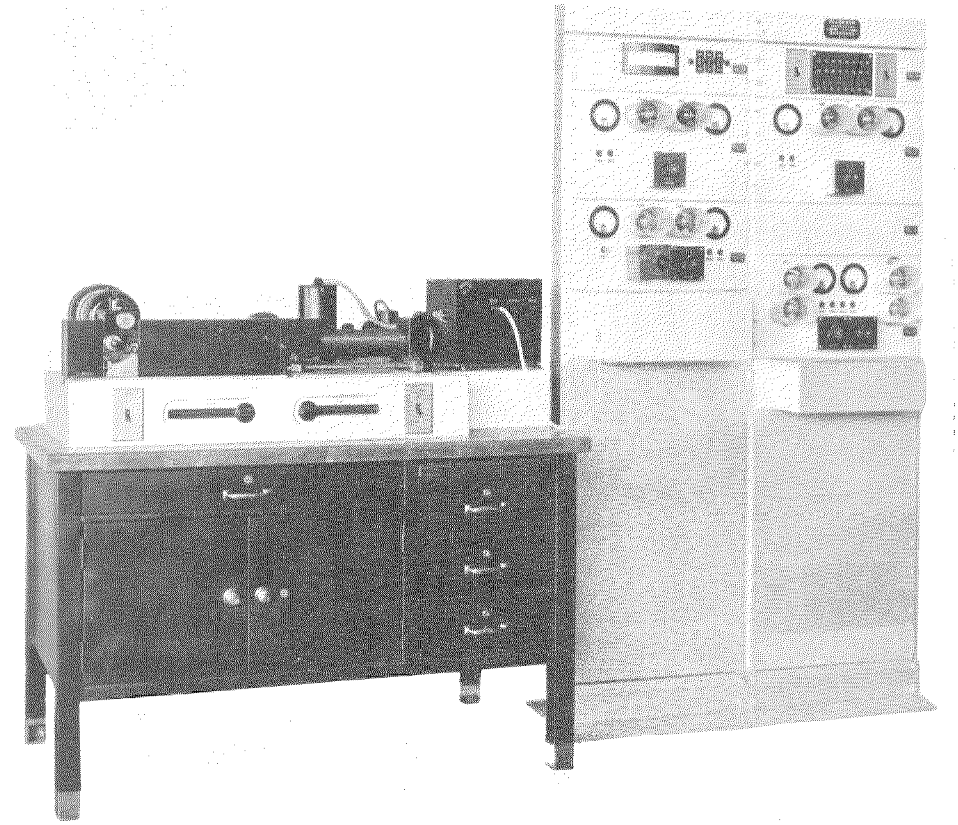


Figure 2—Sending Apparatus.

flux oscillates to both sides and passes through the right and left openings. As the larger the amplitude of oscillation the more will be the amount of the light passing through the openings, it is evident that the received picture will be in negative. In this case the optical part should be adjusted so that the deflected spot comes at its maximum amplitude, as shown in Figure 4-2.

Provided the screen has an opening at its central position (Figure 4-P), all the reflected light flux will pass through this portion. Now if current is flowing in the vibrator, it will be easily recognised that the greater the amplitude of oscillation of the light spot, the less will be the amount of light passing through the central opening; therefore a positive picture will be produced upon the sensitizing paper.

Curves in Figure 5 show the relation between the deflection of the mirror and the light volume passing through the openings in both cases above mentioned. The natural frequency of the vibrator for No. 1 Set is nearly 17,000 cycles and for No. 2 Set nearly 6,000 cycles.

Synchronizing Device

A synchronous motor, which is directly coupled with a D.C. motor working from an independent source at the sending office, is used for driving the drum. These two motors, in conjunction with corresponding motors at the receiving terminal, drive the sending and receiving drums in synchronism. Synchronizing current is generated at the sending terminal by a tuning-fork oscillator. A part of the output from this oscillator is employed to drive the synchronous motor at the sending end, and the remaining part is sent over the line, superposed upon the picture current. These two currents, since they differ in frequency, can be easily separated by the aid of a suitable filter inserted at the receiving end.

For the No. 1 Set, a synchronizing current of 200 cycles per second is employed while for No. 2 Set, 300 cycles is used on account of the increased attenuation at lower frequencies in cable circuits.

For satisfactory picture transmission the sending and receiving drums should be strictly maintained in their corresponding positions during operation while keeping their speeds in synchronism. In this instrument, the driving apparatus is running continuously; the sending or receiving picture drums are arranged so that they can be fitted on the driving shaft in their correct position during one revolution. Providing the speed remains constant, no matter how often the sending or receiving drums are started or stopped they will always be in the same relative positions. Hence it is necessary before starting to work, to ensure that the joint of the picture is in the correct position at the sending end as well as at the receiving end. This is done as follows: on the picture clip at the sending end is a white line, whilst the rest of the drum is black; on rotating the drum, without traversing it, a rush of picture carrier current indicating the white line will be sent to the circuit. At the receiving end the amplifier is switched so as to

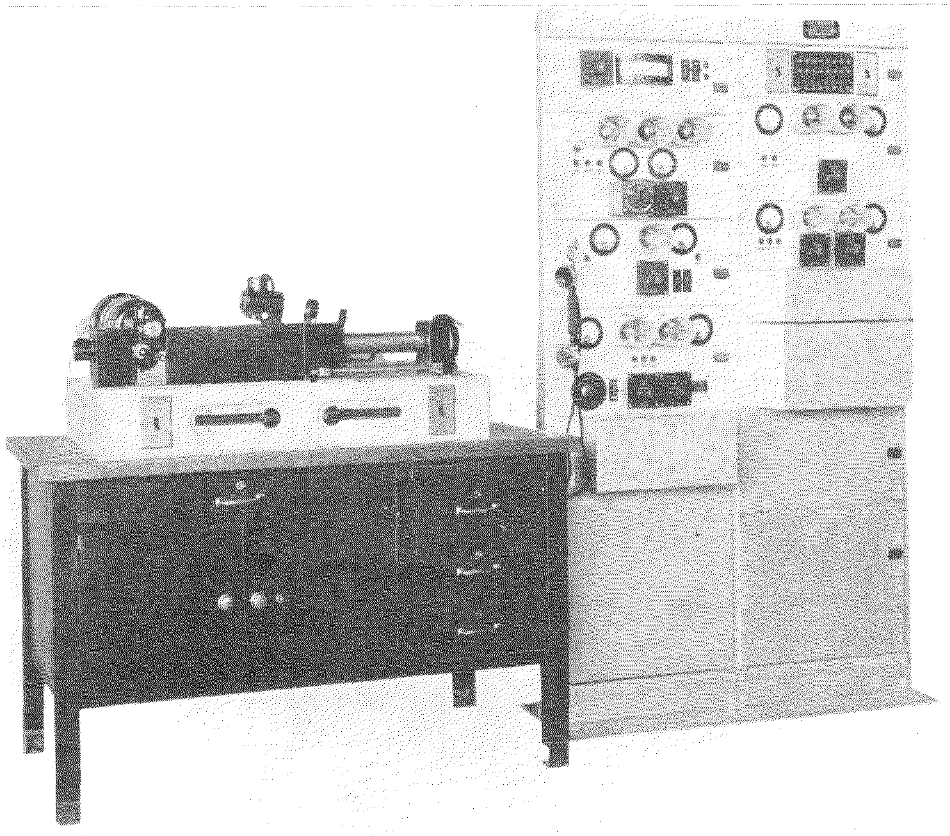


Figure 3—Receiving Apparatus.

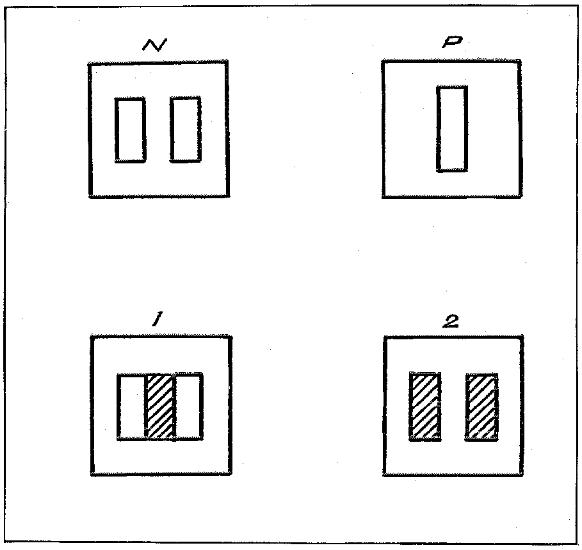


Figure 4—Intercepting Screen.

light a small neon lamp placed in the box; a tinted celluloid cylinder fixed on the same shaft as the receiving drum revolves round the lamp. If the drum revolves in coincidence with the sending drum, a black line on the celluloid cylinder comes to a hole of the box at the instant the neon lamp is lighted, therefore the light can not be seen when peeped at through the hole; if on the other hand a red or yellow light can be seen it is necessary to shift the phase in the proper direction by rotating the stator of the synchronous motor until the light is out of sight. This may be understood by referring to Figure 6.

Signalling System

Conversations over the line by the telephone apparatus provided with No. 1 equipment can be carried on even when a picture is being transmitted. If a signalling key is switched at the sending end so that the filament circuit of an oscillation valve is closed, a signalling current of approximately 1000 cycles is sent out to the line. At the receiving end this current, after being separated from the picture or synchronizing current by a band pass filter cutting off below 300 cycles and beyond 2000 cycles, is amplified, rectified and then passed to a relay which operates a bell. When the key is restored, the filament circuit is opened and the signalling current stops; the answering signal may be sent from the receiving end in the same manner. When the telephone receivers are removed from the hooks at both ends, the telephone circuit is closed so that conversation is possible.

In the case of No. 2 Set, telephone apparatus fitted with a loud speaker is usually connected to the line and conversations can take place except when a picture is being transmitted. When the picture transmission is to be started the line must be connected to the phototelegraphic apparatus instead of the telephone set by changing a switch, but listening can take place over one pair of the 4-wire cable circuit, while a picture is transmitted over the other. A carrier telegraph apparatus is also arranged for transmitting telegraph signals from the picture sending office to the receiving office without stopping the revolution of the motor.

Repeaters

In the case of No. 1 Set, the maximum transmission loss of the carrier current on the aerial line between Tokyo and Osaka is estimated to be about 35 db., consequently a repeater was inserted at the Nagoya Central Telephone Office in order to amplify the current. This

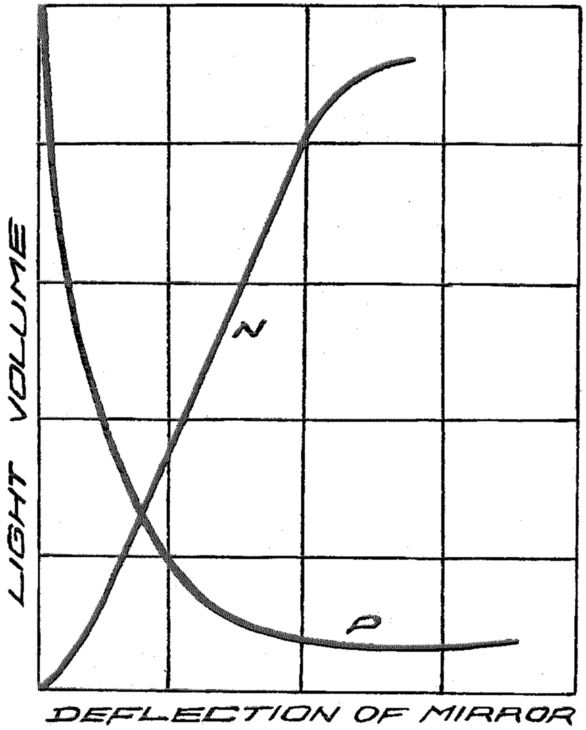


Figure 5—Relation Between Deflection of Mirror and Light Volume Passing Through Openings of Intercepting Screen.

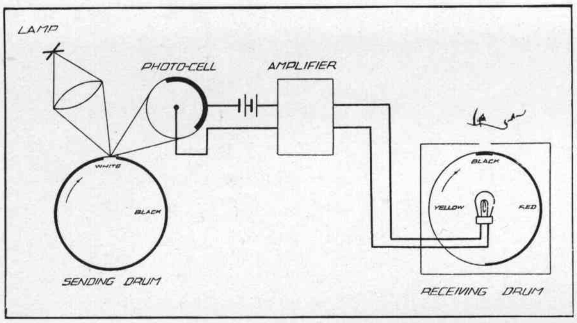


Figure 6—Schematic Diagram of Method of Adjusting Sending and Receiving Drum for Synchronism.

repeater was designed for one-way operation only and in order to save the trouble of manually changing the connection according to the direction of the picture current, an automatic changing system was devised utilizing the synchronized current transmitted from the sending office.

Figure 7 shows the schematic diagram of the repeater. VF is a band pass filter for the voice current, SF the low pass filter for synchronizing current, and PF the high pass filter for the picture current. The main part of the synchronizing current passes through the low pass filters SF, SF′, and is sent to the receiving end; the remaining part is rectified by the 102-D valve and operates the relays; with the result that when the relay R4 or R4′ is operated the input terminals of the amplifier are connected to the sending side and the output terminals to the receiving side. The gain of the repeater is about 25 db. for the 6000 cycle carrier current. The synchronizing current and the voice current are not amplified in this repeater because their transmission losses over the line are comparatively small. Figure 9 gives the attenuation-frequency characteristics for the two sections Tokyo-Nagoya and Nagoya-Osaka.

As to No. 2 Set, 4-wire repeaters are installed at Yokohama, Ejiri, Toyokawa, Kameyama, and Osaka on the cable circuit. The resulting attenuation between Tokyo and Osaka is about 8 db.

Line Arrangement

The arrangement of the aerial telephone line for No. 1 Set is shown in Figure 8, the length of which is about 600 km., and chiefly consisted of 4.00 mm. copper wire. The use of other kinds of wire was avoided as far as possible in order to

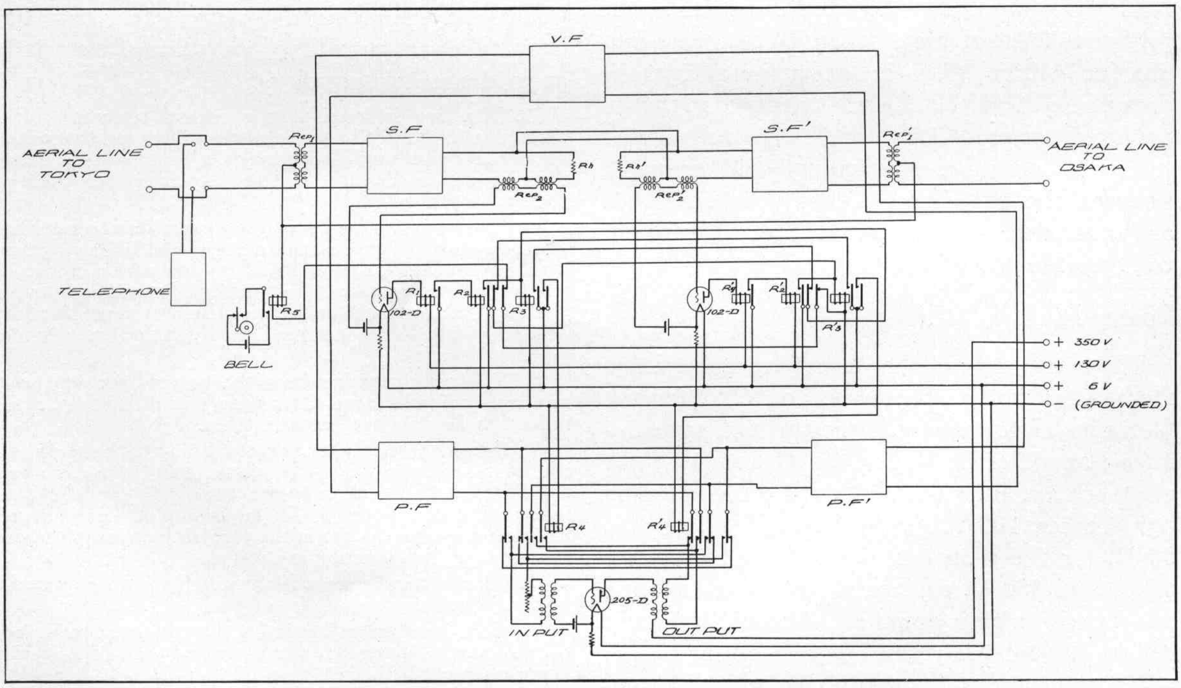


Figure 7—Schematic Diagram of Repeater.

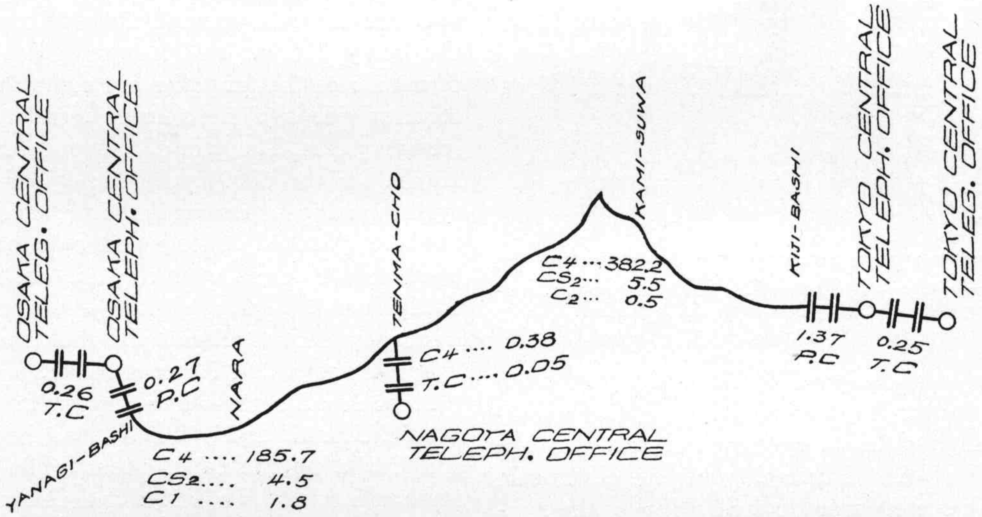


Figure 8—Arrangement of Aerial Telephone Line for No. 1 Set.

keep the characteristics of the line smooth and constant, that is, they must not vary appreciably throughout the transmission range and transmission must be free from echoes and other irregularities.

This line was carried by the same poles as the private toll line of the Nippon Dempo Tsushin-Sha on which picture transmission by the Siemens system (6500 cycle carrier current) is operated between Tokyo and Nagoya. In order to avoid inductive interference and crosstalk between the two circuits, they were separated as far as possible on the pole route and frequent transpositions were made.

Power Plant

The main parts of the phototelegraph system are fed by storage batteries, i.e., 6 V. for the filaments of tubes of the picture and synchronizing amplifier, 2 V. for the filaments of the photocell amplifier tubes, 12 V. for the scanning lightsources, 100 V. for the driving D.C. motors, 50 V. for the plates of the photocell amplifier tubes and 350 V. for the plates of the picture and synchronizing amplifier. The photoelectric cell in use, made by the Tokyo Electric Co., is a flat type gas filled potassium cell with a diameter of about 6 cm., the cathode being deposited with potassium hydride. The anode of the cell is connected to a 120 V. dry battery.

Precautions of Installation

From the point of view of obtaining the best quality in the received picture, great care has been taken in installing and wiring, expecially as to the following points:

1. The line is led into the central telegraph office through a 12-pair lead-covered paper cable from the central telephone office and connected to a terminal board and then by means of a lead-covered 2-pair rubber cable to the apparatus.
2. The batteries for the photocell amplifier are enclosed in a lead lined box to secure perfect shielding against extraneous disturbances and lead-covered wire is employed to the distributing panel. Furthermore, the wiring between the distributing panel and the apparatus is provided by a high grade rubber insulated wire guarded in a copper pipe.
3. The supply mains from the battery are separated as far as possible from other wiring in order to prevent induction disturbance between them.
4. The leads to the apparatus from the batteries for the filaments, the plates of picture and synchronizing amplifiers and the lightsource are high grade rubber insulated wires protected by an iron pipe. Similar precautions have been taken in the case of the wiring between the sending and receiving apparatus.
5. All the wire is separated carefully from power and lighting circuit.
6. Care is taken to minimize the electrical resistance of the joints of iron or copper pipes and each pipe section is perfectly earthed.
7. Oil layer is used to keep the storage batteries free from acid spraying.

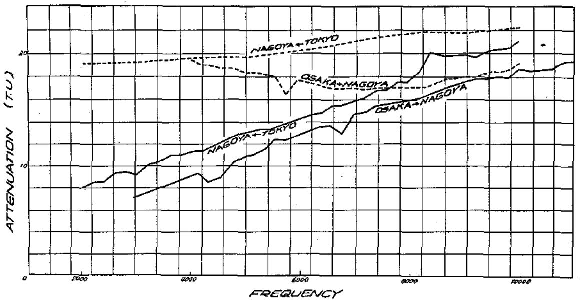


Figure 9—Attenuation-Frequency Characteristics of the Two Sections Tokyo-Nagoya and Nagoya-Osaka.

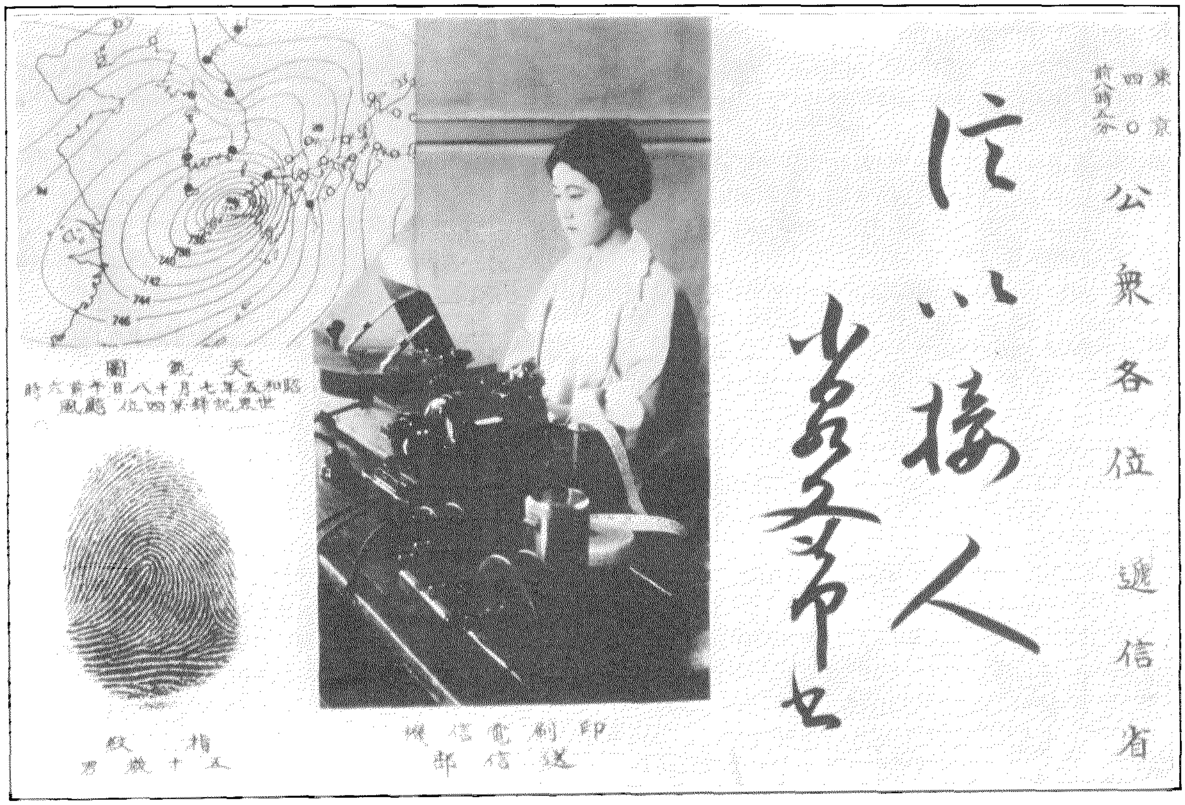
8. Special design is provided in the dark room for close shutting of light, ventilation, supplying and draining water, illumination, doors, double windows to hand over phototelegrams, and voice tubes.

9. Developing and printing can be done by convenient arrangements. Special dryer and washer are also provided.

Service

On the opening day of the public service, nearly 70 phototelegrams were accepted, most of which were in the nature of demonstrations, such as new fashions in dresses and trinkets, samples of goods, commercial advertisements, cinema stars, etc. But on the occasion of the great earthquake in the Izu district on November 26th, 1930, photograms of the pitiable state of the destroyed places, maps of the affected area, the wave forms recorded on the seismometer, etc., were transmitted. The cable circuit was interrupted by the earthquake and consequently the No. 1 Set, working on the open wire line, was operated during this time and over 90 phototelegrams were sent out without any undue delay. The authorities were, therefore, by this means advised almost instantaneously of the terrible conditions in the affected area and were able to arrange for the relief of the people suffering from the disaster.

The charge between Tokyo and Osaka is 5.00 yen for the size up to cabinet size (18 x 13 cm.) and 8.00 yen for the larger size. The amount of traffic is nowadays relatively small, except in the case of some notable event, but with popularization of phototelegraphy and technical simplification of equipment and operation, the future of phototelegraphy will be assured.

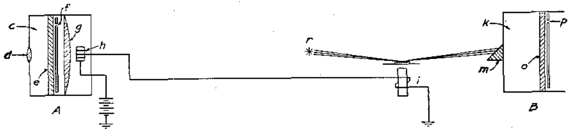


Specimen of Picture Transmitted Over Nippon Electric Phototelegraph System Between Tokyo and Osaka

An Early Television and Picture Transmission Proposal

EDITOR'S NOTE: The television and picture transmission scheme herein described is of special interest inasmuch as it was devised in 1902, 29 years ago, jointly by Mr. J. L. McQuarrie, then Assistant Chief Engineer of the Western Electric Company and now Chief Engineer of the International Telephone and Telegraph Corporation, and by Mr. W. W. Cook, then Chief Engineer of the International Western Electric Company, London, England. At that time photoelectric cells, Neon lamps and vacuum tube amplifiers were, of course, not available; nevertheless, the scheme embodies the fundamental ideas of practical television and picture transmission. The description is taken verbatim from the original manuscript signed by J. L. McQuarrie and W. W. Cook.

The following is a description of apparatus designed for transmitting views or pictures to a distance, jointly invented by the undersigned during the period elapsing between September 29th and October 11th, 1902.



At the transmitting station (A) there is provided a dark chamber (*c*) having a suitable lens (*d*) in an opening at the front. Inside the chamber, exposed to light rays entering through the lens is a ground glass plate (*e*). Immediately behind this plate is a contrivance with a pin-hole opening (*f*) arranged to be rapidly and continuously exposed to every point on the surface of the plate. Next in order is a lens (*g*) adapted to focus light rays passing through the pin-hole to the center of the chamber at the rear. At this focal point there is provided a substance such as selinium (*h*) which is susceptible to changes of electrical resistance under varying intensities of light. The selinium or other responsive substance is included in an electric circuit which extends to the distant receiving station (B) where it is joined to an electromagnet or other device (*i*) capable of responding to changes of E.M.F.

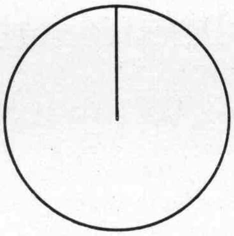
In the illustration an electromagnet is shown; the armature of which is fitted with a mirror.

A suitable dark chamber (*k*) is provided at (B); this chamber is equipped with a semi-opaque prism (*m*) at the rear. Inside the chamber is a ground glass plate (*o*) and in front of this plate is a device for exposing a pin-hole (*p*) to every point on the surface similar to that employed at the transmitting station.

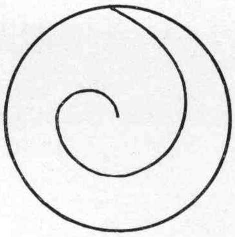
In the operation of the apparatus a source of light (*r*) is provided at the receiving station so arranged that its rays are reflected to the prism at the rear of the chamber by means of the mirror attached to the armature of the electromagnet. In tracing the sequence of events which occur in the use of the apparatus it will be observed that light rays reflected from the view pass through the small lens into the chamber at the transmitting station and are impressed on the ground glass plate therein. The pin-hole passes over the surface of the plate at a speed which enables it to cover the area in about one-sixth of a second, thus exposing all points on the plate's surface in rapid succession and permitting the light rays to pass into the large lens at the rear; these rays being more or less intense depending upon the degree of light or shade of the particular point of the view at which the pin-hole is located at a particular moment. It follows therefore that the selinium cell is subjected to light rays of varying intensity and this in turn causes corresponding changes in its electrical resistance, followed by similar variations in the strength of current in the electric circuit. The current changes are reproduced at the receiving station in the form of mechanical movement of the armature of the magnet and the beam of light which is reflected from the mirror attached to the armature is caused to waver in harmony with this motion. The reflected beam will then sweep across the surface of the semi-opaque prism located in the opening at the rear of the receiving chamber. When the light beam is at the upper edge of the prism practically all the rays will pass into the chamber and its interior will be illuminated; when the beam is at the lower portion of the prism none of the rays can enter and the chamber will be dark. As the beam moves across the prism a gradual change from a condition of light to one of darkness occurs inside the chamber. It will thus be seen that if the pin-hole at the receiving station is caused to move over the surface of the ground glass plate located within the chamber the particular point at which the pin-hole may be situated at a given moment will appear to the observer to be either light or dark depending upon the condition inside the chamber. If then the pin-holes at both stations are operated with synchronism the view impressed on the ground glass plate at the transmitting station will be reproduced on the plate at the receiving station.

The pin-hole mechanism may consist of two discs placed one in front of the other and arranged to revolve at proper speed; one of the discs may have an opening or slot cut across its face from the center to the periphery as in sketch (E) below, the other disc may have a spiral slot extending out from the center as in sketch (G).

If the speeds at which the discs are revolved bear the proper relation to each other, the effect of a spirally revolving pin-hole will be produced.



E



G

In place of the apparatus shown at the receiving station for deflecting the beam of light it is suggested that an electric arc be used and means be provided in the line for varying its intensity.

It is proposed that for the purpose of transmitting photographs or views of stationary objects a photographic plate be used at the receiving station and formed through the action of the mechanism. This may be accomplished with comparatively slow changes in the transmitting medium.

It is pointed out that for short distances a direct beam of light may serve as the medium of transmission between the two stations.

Ten Years of Full Automatic Telephone Service in Oslo

By M. L. KRISTIANSEN

Telephone Director, Oslo

SUMMARY—*This paper discusses the splendid results achieved by the Administration with rotary automatic after conversion from an inadequate magneto system. The equipment has completely fulfilled expectations and has made possible the introduction of several modern appliances and methods such as message rate instead of flat rate service, and "automatic subscriber" test machines. Operating expenses per line per year from 1921 to 1930 were reduced over 50%, and complaints per subscriber per year in 1929-30 decreased to 1.37.*

THE full automatic telephone system in Oslo, one of the largest of the Standard Electric Company's No. 7-A rotary automatic installations in one city in Europe, has now been in operation for ten years, the first of the nine exchanges being opened for service on January 23, 1921. The installation and reconstruction of the outside plant was started in 1916 and was not finished until 1927, the delay being due to the many difficulties arising from the war. The last exchange was cut over in November, 1927. The total number of subscribers' lines is now 36,000, with 48,000 subscribers' stations and 400 manual and automatic private branch exchanges.

The general layout of the system, the size of the exchanges in 1925, and the technical details have already been described,[1] but some of the experience gained from the actual operation of the system during these ten years may prove of interest.

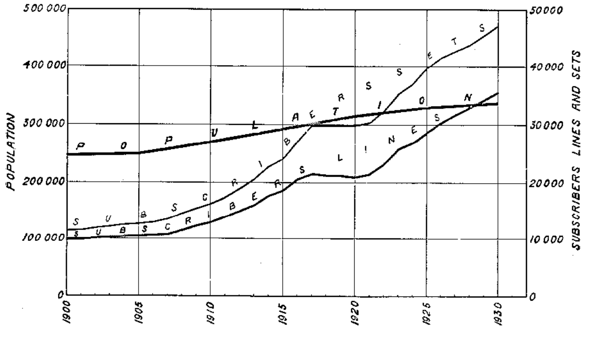


Figure 1—Population and Number of Telephones in the Oslo Area.

Before the introduction of the automatic system Oslo had a somewhat inadequate magneto system which was installed in 1896. In spite of considerable sums of money spent on its maintenance, the old system was very unsatisfactory during the last ten years of its operation. As soon as the first automatic exchange was opened for service, a decided improvement was evident and conditions continued to improve rapidly with the opening of each new exchange.

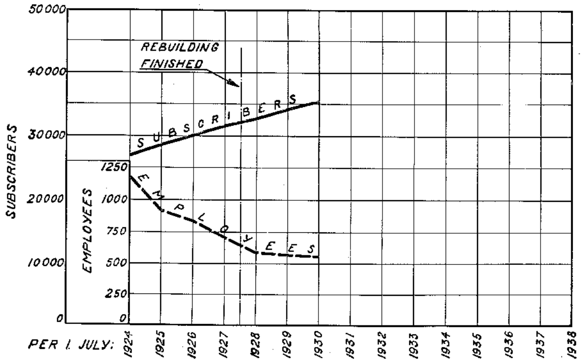


Figure 2—Subscribers' Lines and Employees of All Ranks.

It is significant that during the actual transition period of six years not a single complaint was made in the newspapers against the new system or the work of transition. On the contrary the public was unanimous in its praise of the new system and specially requested to be connected with it.

Certain difficulties were expected due to the fact that a change was made from an old type magneto system which had outlived its useful life, to the most modern full automatic exchange system, without the usual intermediate step of manual central battery working. During the transition period the traffic between the automatic system and the manual exchanges was handled on a call indicator and semi-B basis.

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[1] M. L. Kristiansen, "Full Automatic Telephone System in Kristiania-Norway," *Electrical Communication*, Vol. III, No. 4, April, 1925.

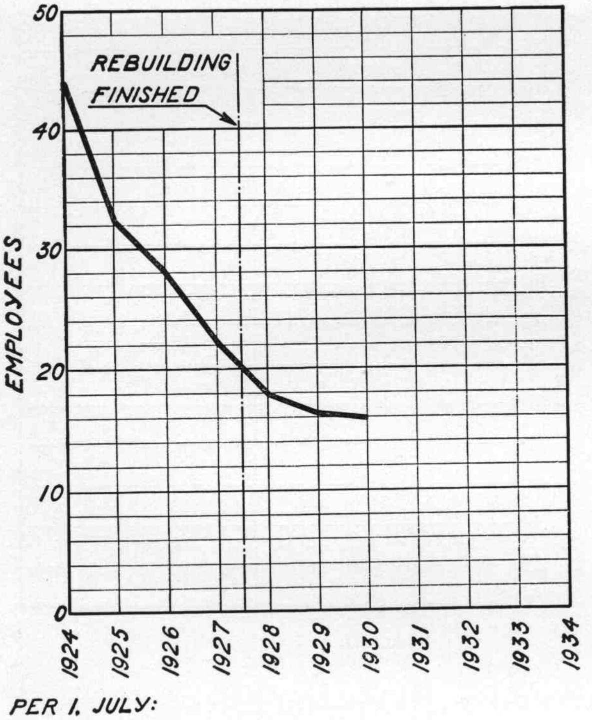

Figure 3—Employees per 1,000 Subscribers Lines.

Since the reconstruction, which was finished in 1927, there has been general satisfaction with the system and its operation. Both the subscribers and the Administration agree that the automatic system has fulfilled all that was expected of it and, at the same time, has made possible the introduction of several modern appliances and methods. The reduction in operating expense in connection with the introduction of a more equitable tariff—the message rate instead of the flat rate—has enabled the Administration to make the service cheaper, especially for the smaller and residential user, with the result that nearly 70% of the subscribers now have a cheaper telephone service than under the old and unsatisfactory manual system.

Referring to the curve in Figure 1, it will be seen that growth was stagnant from 1917 to 1921. This was primarily due to the inadequacy of the old exchange equipment, and was further accentuated by an increase of traffic during this period, when it was consequently found impossible to connect new subscribers. New subscribers could only be connected as old subscriptions were given up.

Figure 2 shows how the number of employees of all ranks and workmen has been reduced during the transition period, although the number of subscribers has increased.

Figure 3 shows the number of employees and workmen per 1,000 subscribers.

Figure 4 illustrates the improvement in the service after the conversion to the automatic system was finished. The complaints per subscriber per year show a decrease from 3.4 to 1.37. The curves in Figure 5 show the total number of faults per subscriber per year for outside lines, subscribers' station equipment and exchange equipment, also the sum of all these faults. As will be observed, the total number of faults in 1930 was 1.47 per subscriber. This figure includes faults found during routine tests, inspection, etc., i.e., faults or troubles which have not given rise to complaint from the subscribers.

The curve in Figure 6 shows the economic result, or the operating expenses per subscriber from year to year. From 1921 to 1930 these expenses have been reduced from 156 kr. to 69 kr. per annum, excluding interest and depreciation.

In the financial year 1929 to 1930, the com-

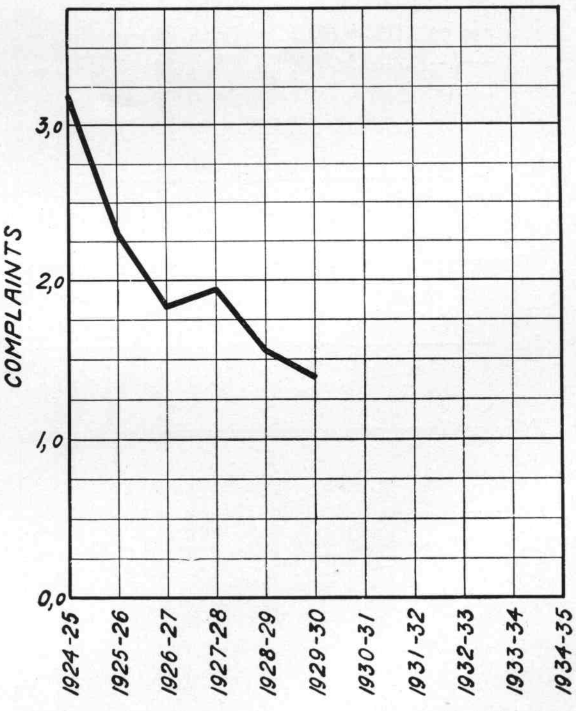

Figure 4—Complaints Per Line Per Year.

plaint and fault service shows the following figures:

Total No. of Complaints	47,694
Total No. of False Calls	7,452
Total	55,146
There were:	
Actual Faults	33,498
Faults and irregularities found during routine tests and inspection	17,554
Total faults and irregularities	51,052
No. of complaints per line	1.375

Total number of faults per line including faults and irregularities found on inspection and routine tests:

(1) Exchange faults	0.436
(2) Substation apparatus faults	0.797
(3) Outside Plant Faults	0.241
Total per line	1.474

The traffic figures are rather high, varying from an average of 4.2 in the satelite exchanges to 14.5 calls per day per line in the Centrum exchange (City) corresponding to 0.75 and 4.35 busy hour calls, respectively.

The total number of calls in the year 1929–1930 was 110,702,448. During the same year 1,227,552 calls were sent through the exchanges by means of "automatic subscriber" test machines with the following results:

Effective calls	99.6%
Wrong Calls	0.2%
Lost Calls	0.2%

or an overall efficiency of 99.6%.

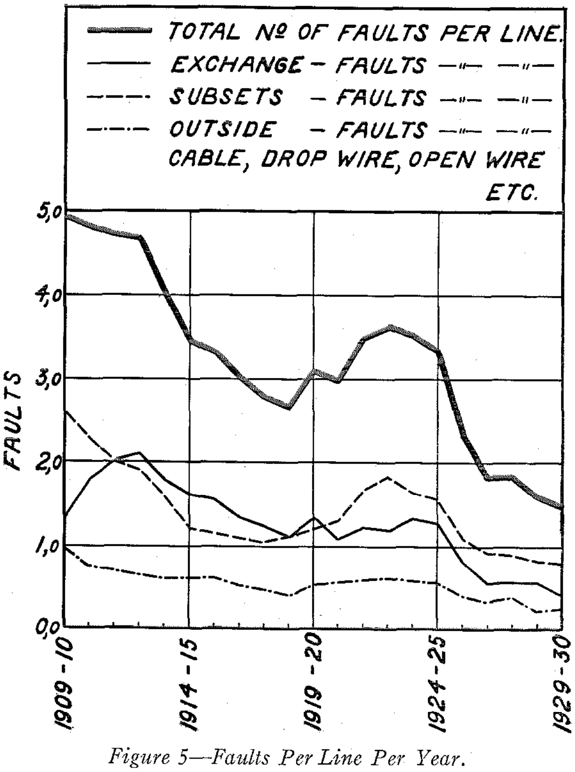

Figure 5—Faults Per Line Per Year.

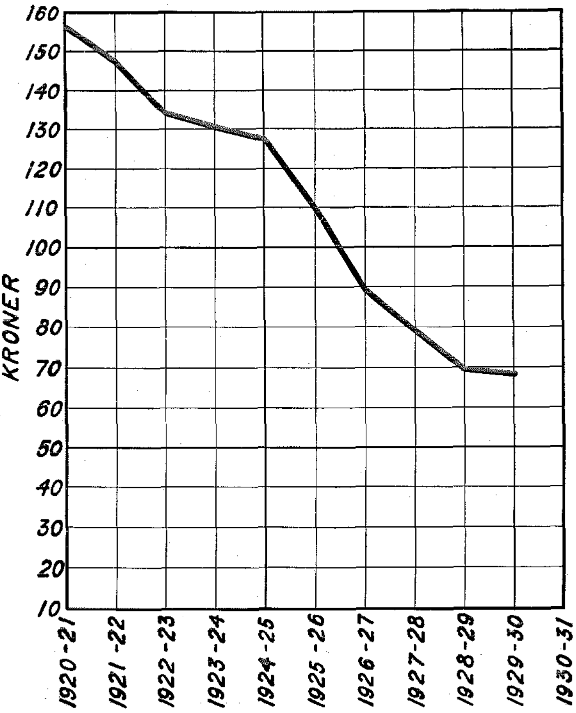

Figure 6—Operating Expenses Per Line Per Year.

As a further illustration of the splendid operation of the system, during the month of February this year 1000 check calls were made from subscribers' stations in the Central Nord area, it being found by observation that no fault of any description occurred.

The new tariff which was introduced simultaneously with the cutting over of an exchange or a group of subscribers to the automatic system is made up of a fixed tariff of 108 kroner per year and 5 öre (minus a discount of 5%) per call.

In the financial year 1929–1930 the subscribers' use of the telephone was:

12%	of the subscribers made from	1 to 500 calls
23.4%	" " " "	500 — 1000 "
18.9%	" " " "	1000 — 1500 "
13%	" " " "	1500 — 2000 "
15.3%	" " " "	2000 — 3000 "
7.7%	" " " "	3000 — 4000 "
5.9%	" " " "	4000 — 6000 "
1.8%	" " " "	6000 — 8000 "
2.0%	" " " "	over 8000 "

Telephone Condensers

By R. E. W. MADDISON and S. CHAPMAN

Engineering Department, Standard Telephones and Cables, Limited

Introduction

IN many branches of electrical engineering there is a large demand for a condenser of moderate cost, not requiring the extreme constancy in capacity and low power factor obtainable with mica or air condensers. This demand is met by a condenser having a dielectric of wax-impregnated paper, and electrodes of metallised paper or metal foil.

The number of such condensers used in the telephone industry is very great. For example, an 8,000 line step-by-step automatic telephone exchange requires about 15,000 paper condensers; and, in addition, one condenser is needed for each sub-set installed on the subscribers' premises. Large quantities also go into repeater and carrier equipments, as well as into radio transmitting and receiving sets. They are used to carry speech and signalling currents and, in conjunction with resistances, to quench the sparking which occurs at contacts on breaking certain types of inductive circuits.

The purpose of this paper is to describe the production and properties of paper condensers, but no discussion of the theories of dielectrics will be attempted.

Materials

For the manufacture of the type of condenser here being dealt with, there are three basic materials:

(1) The paper utilised as an interleaf to separate the electrodes, and to support the impregnating medium.

(2) The metal foil or metallised paper serving as the conductors or electrodes.

(3) The impregnating medium which, in combination with the paper, constitutes the dielectric between the conductors. The resulting dielectric is required to possess high electric strength, insulation resistance, and dielectric constant.

Paper

The paper employed in these condensers is prepared from rag stock, and is the thinnest and purest produced commercially. The thickness is from 0.007 to 0.020 mm., and a sample usually does not vary more than ± 0.001 mm. from the average. A 0.011 to 0.013 mm. paper would have a weight of 12–14 grams per square meter according to its density. The ash value is not greater than 0.5%. During manufacture, particular attention is directed towards producing a paper that is free from mechanical impurities (metallic particles), salts (chlorides), acid or alkali.

Electrodes

Paper condensers may be grouped in two classes:

(a) Foil type.

(b) "Mansbridge" type.

according to the nature of the material serving as the conductors or electrodes.

(*a*) *Foil Type*——

In this type, thin metal foil constitutes the conductor. In the early days of condenser manufacture tin foil was the only suitable material available, but it has been displaced to some extent by aluminium foil. Sometimes pure tin and sometimes tin-lead alloys are employed. In order to enable the tin to be rolled to the required thinness (about 0.012 mm.) a small percentage of antimony is added.

Within the last five years, aluminium foil (99% pure) rolled to an extraordinary degree of thinness has become available commercially. Foil 0.006 mm. can be obtained, but material about 0.008 mm. is generally employed. It is to be noted that this is about one-half the thickness of the paper employed in the condenser. The production of such thin foil as a uniform product on a commercial scale, is a remarkable achievement. Comparison of certain of the properties of tin and aluminium show the advantages of using aluminium.

	Tin	Aluminium
Density	7.3	2.7
Covering power per kilo in square meters for foil 0.010 mm. thick	13.8	37.2
Specific resistance at 20°C. in microhms per cubic centimeter	13.0	2.8

Although the price of aluminium foil per kg. is higher than that of tin, it is cheaper to use the aluminium on account of its greater covering power.

(*b*) *"Mansbridge" Type*——

G. F. Mansbridge[1] conceived the idea of utilising instead of foil a paper covered with a thin conducting layer of tin, in order to effect an economy of material.[2] The electrical conductivity of the metallised paper varies between 25% and 50% of that of a pure tin foil of the same thickness of metal, but it is sufficient for the purpose for which the paper is required. The Mansbridge paper is no thicker than ordinary condenser tissue, namely 0.012 mm. and weighs about 25 grams per square meter.

Recently it seemed as though the Mansbridge metallised paper would be displaced entirely by aluminium foil, but it appears that the former material has obtained a new lease of life in connection with recent developments in condensers for spark-quench circuits referred to hereinafter.

IMPREGNATING MEDIUM

Paraffin wax is the material generally used for impregnating paper condensers. Small quantities of other substances are sometimes added when it is desired to modify the physical properties of the wax. Materials of higher dielectric constant have also been found of use for impregnating purposes. The main advantage is that a smaller unit is obtained, but generally the electrical properties of the condenser are not so good as when paraffin wax alone is used. As in the case of the paper, the purity of the impregnating medium with regard to its freedom from mechanical impurities and acid is of great importance, and is carefully controlled.

Process of Manufacture

The following stages are passed through in the course of production of a condenser.

1. Winding of the unit.
2. Drying.
3. Impregnating.
4. Cooling.
5. Sealing.
6. Potting.

A power driven winding machine is employed. It is fitted with a revolution counter and adjustable friction brakes on the spindles carrying the rolls of paper and foil to prevent overwinding. Two metal foils separated by sheets of interleaving tissue are wound spirally, and the metal tapes which enable external connection to be made to the foils are inserted by hand at the most suitable positions as the winding progresses.

To produce a condenser having high insulation resistance, it is essential for the wound unit to be thoroughly dried before it is impregnated. Although drying may be carried out in various ways, one method frequently adopted is to place batches of wound units in ovens heated to about 110°C. After a certain time they are removed to heated pans and evacuated. The units are then impregnated and cooled under presses. When completely cooled, they are dipped in a bituminous compound which effectively seals and prevents them from absorbing moisture.

The harmful effect of moisture is well illustrated by the following results obtained on unsealed units.

(1) Exposure for one hour in an atmosphere of 50% relative humidity reduced the insulation resistance to 2/3 of its original value.
(2) Exposure for 16 hours in an atmosphere of 100% humidity reduced the insulation resistance to 1/400 of the dry value.
(3) Further exposure for 4 hours in an atmosphere of 50% relative humidity raised the insulation resistance to 15 times the value given in (2).

When the sealed units have cooled down, they are tested for capacity and insulation resistance. If they pass these tests, they are fitted with terminal plates, after which they are placed in their cans and completely covered with a bituminous compound.

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[1] E. P. 19451/1900.

[2] With regard to its manufacture, see F. Haigh, E. P. 24981/1911.

"Mansbridge" Condensers

The type of condenser invented by G. F. Mansbridge, employing metallised paper as conductors has become known by his name. The processes involved in preparing condensers of this type are no different from those for condensers utilising foil.

"Mansbridge" condensers possess a useful "self-sealing" property which deserves mention. If a breakdown occurs, it very often happens that the current which passes clears the fault by vapourising the tin round the puncture, thus leaving a small area of paper free from metal (Figure 1). This property is shared by foil condensers to a much less extent; but, if a breakdown occurs in one of them, an excess of current will sometimes remove a short circuit.

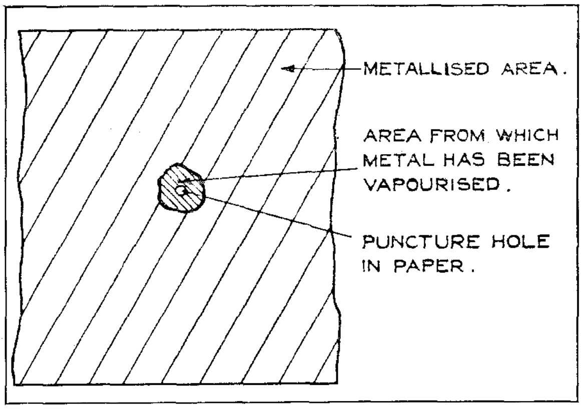

Figure 1

The reason why "Mansbridge" condensers possess this greater self-sealing property may be accounted for by the following theory: Owing to the relatively high resistance of the metallised paper, an arc is formed having a temperature sufficient to vapourise the exceedingly thin layer of tin whereas, in the case of foil, the temperature is not sufficient to vapourise the thicker layer of metal present. In the latter case, breakdowns usually result in the metal of one electrode being blown through the puncture hole in the paper and brought into contact with the other metal foil, thereby causing the short circuit. On the other hand, the breakdown voltage of a "Mansbridge" condenser having a dielectric of one interleaving tissue and one foiled paper is less than that of a tin foil condenser having a dielectric of two interleaving tissues. One foiled paper contributes to the electric strength an equivalent of about one half of that contributed by a plain interleaving tissue.

Ingenious use is made of the ohmic resistance of "Mansbridge" paper in the "inherent resistance condensers" employed in spark-quench circuits. When a coil is carrying current, energy is stored in its magnetic field, and this energy is dissipated as a spark when the circuit is broken. The spark produced at the contacts where the circuit is broken would rapidly destroy them if the inductance of the coil or the current passing through it were great. In order to dissipate the energy harmlessly, a condenser and resistance in series are placed across such contacts. The values of capacity and resistance required depend on the inductance and on the current carried by the circuit. A 200 ohm resistance and a 1 microfarad condenser are satisfactory for a circuit having an inductance of about ⅓ henry carrying a current of about 1 ampere.

The inherent resistance condenser unit consists of long narrow strips of "Mansbridge" paper separated by paper interleaves wound in the usual manner. The terminal connections, however, are made, one to the inner end of one foil, and the other to the outer end of the other foil. The electrical effect is as if the resistance of one plate were connected in series with the condenser.

Electrical Properties

Absorption and Insulation Resistance

Wax-impregnated paper shows to a marked degree the phenomenon of absorption common to all liquid and solid dielectrics. This may be described as a gradual soaking in of the charge to the inner layers of the dielectric.

Consider the case of a condenser with a perfect dielectric,[1] and suppose that at a certain instant the plates are connected to a source of constant E.M.F. Current will flow along the wires of the connecting circuit till the condenser is charged with a definite amount of electricity depending upon its capacity. The magnitude and duration of this current, called the *normal charging current*, can be calculated, and are dependent upon the resistance and inductance of the connecting circuit as well as upon the capacity of the condenser. The inductance and resistance can be made quite small, so that the current falls to a negligible value in a very small fraction of a second. If the condenser has an imperfect dielectric, there will be added to the normal charging current a constant leakage current, called the *normal conduction current*, which will persist after the normal charging current has become negligible and so long as an E.M.F. is applied to the condenser. The magnitude of this current depends upon the value of the applied voltage (V) and upon the insulation resistance (R) of the dielectric, and is given by the expression $\frac{V}{R}$

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[1] i.e., one which has an infinitely high resistance and in which no electrical losses occur. The nearest approach to this ideal is a good air condenser.

When liquids or solids are substituted for gas as the dielectric of a condenser, a third current is observed. As mentioned above, the time required for the normal charging current to become negligible can be calculated. After this time has elapsed, a current which decays with time is found to be flowing. It is called the *anomalous charging current* or *absorption current*, and may take a very long time to disappear. When it has ceased, or can no longer be detected, the constant conduction current remains. A dielectric which exhibits the phenomenon of absorption, produces much the same effect as is obtained by connecting a resistance in series with a perfect condenser, that is to say, it retards the charging or discharging currents. Figure 2 shows the course of the absorption curve for a good paraffin-paper condenser.

Since a considerable time is needed for the steady conduction current, depending on the insulation resistance of the dielectric, to be reached, it is customary in practice to determine the insulation resistance of condensers after an arbitrary period of charging at 300 or 500 volts D.C. The time is usually one minute. The insulation resistance, which is slightly dependent on the value of the applied voltage, is usually expressed for 1 microfarad as the product of the measured resistance in megohms by the capacity of the condenser in microfarads. In the case of telephone condensers, another quantity known as the "absorption" or "electrification" is determined, and is obtained by prolonging the insulation resistance test for another minute. The difference between the galvanometer deflections, which measure the current flowing into the condenser, at the end of the first and second minutes is expressed as a percentage of the value at the end of the first minute.

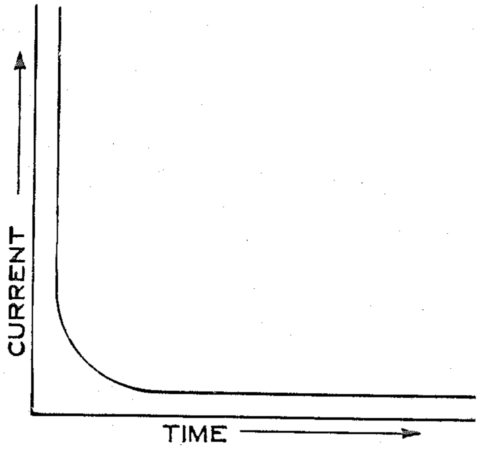


Figure 2

It has been found by experience that poor paraffin-paper condensers show a low absorption as well as a low insulation resistance; this is generally taken to indicate that conducting impurities such as moisture, which allow of a rapid leakage of the charge into the body of the dielectric, are present. There is no strict mathematical relationship between insulation resistance and absorption, but in good condensers high values of both are usually obtained. At a room temperature of 15°C. a good paraffin-paper condenser should possess an insulation resistance of 5,000—10,000 megohms per microfarad and an absorption of 25–30%. The insulation resistance has a fairly high negative temperature coefficient; a rise of 5°C. from 15–20°C. will decrease it by about 25%.

CAPACITY

The capacity of paper condensers for most telephone purposes is not usually required to be within fine limits; it is usually specified to within ± 10%. It is determined by charging the condenser with a 30 volt battery for ten seconds, and then discharging it through a ballistic galvanometer. For some circuits, particularly in repeater and carrier work where condensers are required to carry voice frequency or carrier frequency currents, the capacity has to be more accurately determined, and then the capacity measurement must be carried out on a Wien or Schering bridge at the working frequency of the condenser. The operation of most of the circuits employing paper condensers is not materially affected by capacity changes resulting from the effects of time and temperature.

From what has been said above regarding the phenomenon of absorption exhibited by these condensers, it will be appreciated that they will show a greater apparent capacity for currents of zero or low frequency than of voice or higher frequencies, since in the latter case the time available for the charge to soak into the dielectric during each half cycle is short. At high frequencies the absorption effect disappears and the true capacity approximating to the geometric capacity of the condenser is obtained. The change of capacity with frequency is continuous in the mathematical sense, and at high frequencies is asymptotic to the geometric capacity, *i.e.*, to the true capacity depending only on the geometric dimensions and disposition of the conductors, and the dielectric constant of the dielectric. The capacity-temperature coefficient for good paper condensers is usually negative. A variation in the value of the applied voltage has practically no effect upon the capacity.

POWER LOSSES

If a perfect condenser be connected to an alternating current supply, the current taken by the condenser will lead the voltage by 90°. In practice, however, all condensers are imperfect, so that the angle of lead is less than 90°, and a certain amount of power is degraded into heat within the condenser.

In the vector diagram, Figure 3, V and I represent the voltage and current vectors, respectively, ϕ the phase angle, and θ the phase displacement, or loss angle. If W represents the power in watts lost from all causes in the condenser, V the effective voltage at the terminals, and I_0 the current taken by it, then the power factor of the condenser is

$$\frac{W}{VI_0} = \sin \theta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

It is usual to regard a condenser as being equivalent to a perfect condenser C shunted by a resistance R. Referring again to Figure 3, the current OB taken by the combination may be considered as the resultant of two components OA and AB; OA being the current equal to ω CV (where $\omega = 2\pi$ x frequency) taken by the perfect condenser C, and therefore at right angles to the applied voltage V; and AB being the current equal to $\frac{V}{R}$ taken by the shunt resistance R, and therefore in phase with the voltage. Instead of R, its reciprocal termed the conductance and represented by G, is sometimes used. We have then,

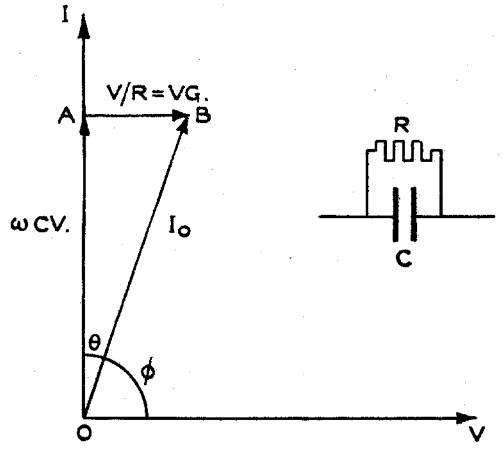


Figure 3

$$\frac{V}{R} = VG$$

From Figure 3

$$C = \frac{I_0}{\omega V} \cos \theta \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\text{and } \tan \theta = \frac{G}{\omega C}$$

When θ is very small,

$$\text{power factor} = \sin \theta = \theta = \tan \theta$$

The power factor may be expressed in terms of the conductance, G. thus

$$\sin \Theta = \frac{G}{\sqrt{G^2+\omega^2C^2}}$$

For small values of power factor, the expression $\frac{G}{\omega C}$ is a sufficiently close approximation, this being the tangent instead of the sine of the loss angle.

In good paraffin-paper condensers, the power factor is less than ½%, which is equivalent to a phase displacement of about 17 minutes. "Mansbridge" condensers exhibit a slightly higher power factor than foil condensers on account of the greater resistance of the electrodes. Combining equations (1) and (2) we have

$$\text{power loss} = W = \omega C V^2 \tan \Theta$$

The power loss may be expressed in terms of the conductance G thus,

$$W = V^2 G$$

For a parallel plate condenser having a plate area A and a dielectric thickness d, this becomes

$$W = \frac{V^2 A \delta}{d} \quad \dots\dots\dots\dots\dots\dots (3)$$

where δ is the specific alternating current conductivity of the dielectric.

It has been found by experiment that $\frac{G}{C}$ is independent of the size or shape of the condenser system, and is a function only of the dielectric material, the temperature, and the voltage gradient. The result may be obtained by the following approximate analysis.

If a condenser has a capacity C_0 when the dielectric is a vacuum, then its capacity C when a medium of dielectric constant $\mathcal{E}$ is substituted becomes

$$C = \mathcal{E} C_0 \quad \dots\dots\dots\dots\dots\dots (4)$$

For a parallel plate condenser

$$C = \frac{\mathcal{E} A \text{ x } 10^{-12}}{3.6 \pi d} \text{ farads} \quad \dots\dots\dots\dots (5)$$

For small values of Θ,

$$\frac{G}{\omega C} = \frac{W}{V I_0} \quad \dots\dots\dots\dots\dots\dots (6)$$

$$\text{and } I_0 = \omega C V \text{ approximately} \quad \dots\dots\dots (7)$$

From (5), (6) and (7)

$$\frac{G}{C} = \frac{3.6 \pi \omega d W \text{ x } 10^{12}}{\omega \mathcal{E} A V^2} \quad \dots\dots\dots\dots (8)$$

Substituting (3) in (8)

$$\frac{G}{C} = \frac{3.6 \pi \delta \text{x} 10^{12}}{\mathcal{E}} = \text{constant x} \frac{\delta}{\mathcal{E}}$$

δ and $\mathcal{E}$ are specific for a given dielectric, and their values are dependent solely upon physical conditions, such as temperature, under which they are determined.

The losses occurring in a condenser are contributed from three sources.

(1) The resistance of the dielectric.
(2) The resistance of the electrodes.
(3) The A.C. conductance of the dielectric.

LIFE TESTS

No satisfactory test has yet been devised which will not only show the quality of the condenser at the time of test, but will also give some indication of its probable life under service conditions. It has been suggested that the measurement of the insulation resistance and/or the power factor immediately after the application of a high A.C. potential would be of value. The object of such a test would be to cause local heating at weak spots in the dielectric. A comparison of the values of the leakage or power factor before and after such a test might be an indication of the quality of the condenser. Permanent life tests on A.C. or D.C. (alone or superimposed) are of value in estimating the worth of a condenser, but such tests should be carried out in conjunction with determinations of insulation resistance and power factor. They have the great disadvantage of requiring a very long time, months or years, for their completion.

Telephone and Telegraph Statistics of the World

Compiled by Chief Statistician's Division, American Telephone and Telegraph Company

Telephone Development of the World, by Countries
January 1, 1930

	Number of Telephones			Per Cent of Total World	Telephones per 100 Population	Increase in Number of Telephones During 1929
	Government Systems	Private Companies	Total			
NORTH AMERICA:						
United States	—	20,068,023	20,068,023	58.12%	16.4	891,715
Canada	247,642	1,152,344	1,399,986	4.06%	14.2	65,452
Central America	11,892	12,739	24,631	.07%	0.4	974
Mexico	1,427	80,268	81,695	.24%	0.5	3,724
West Indies:						
Cuba	485	76,332	76,817	.22%	2.1	3,104
Porto Rico	404	11,856	12,260	.04%	0.8	—716
Other W. I. Places*	9,303	11,252	20,555	.06%	0.3	573
Other No. Am. Places*	100	11,309	11,409	.03%	3.2	1,214
Total	271,253	21,424,123	21,695,376	62.84%	13.0	966,040
SOUTH AMERICA:						
Argentina	—	279,990	279,990	.81%	2.5	40,410
Bolivia	—	2,507	2,507	.01%	0.1	—176
Brazil	§ 674	159,283	159,957	.46%	0.4	30,128
Chile	—	45,239	45,239	.13%	1.0	3,123
Colombia	2,297	26,075	28,372	.08%	0.3	5,972
Ecuador	§ 1,454	2,693	4,147	.01%	0.2	*—100
Paraguay	185	1,785	1,970	.01%	0.3	907
Peru	—	13,299	13,299	.04%	0.2	—566
Uruguay	—	29,022	29,022	.08%	1.6	893
Venezuela	§ 668	19,182	19,850	.06%	0.6	5,217
Other So. Am. Places	2,768	—	2,768	.01%	0.5	49
Total	8,046	579,075	587,121	1.70%	0.7	85,857
EUROPE:						
Austria	222,236	—	222,236	.64%	3.3	12,766
Belgium	259,673	—	259,673	.75%	3.2	33,828
Bulgaria	18,505	—	18,505	.05%	0.3	1,414
Czechoslovakia	142,413	15,294	157,707	.46%	1.1	13,399
Denmark (March 31, 1930)	13,309	328,490	341,799	.99%	9.6	10,751
Finland	1,314	120,750	122,064	.35%	3.3	7,273
France	1,056,034	—	1,056,034	3.06%	2.5	90,515
Germany	3,182,305	—	3,182,305	9.22%	5.0	231,875
Great Britain and No. Ireland	1,886,726	—	1,886,726	5.47%	4.1	127,040
Greece*	13,000	—	13,000	.04%	0.2	3,000
Hungary	100,590	—	100,590	.29%	1.2	7,431
Irish Free State (March 31, 1930)	27,992	—	27,992	.08%	0.9	1,054
Italy (June 30, 1930)	—	381,992	381,992	1.11%	0.9	48,935
Jugo-Slavia	66,863	—	66,863	.19%	0.4	* 5,000
Latvia (March 31, 1930)	42,189	—	42,189	.12%	2.2	7,742
Netherlands	284,433	—	284,433	.82%	3.6	28,944
Norway	† 111,238	* 77,000	188,238	.55%	6.7	3,341
Poland	102,465	83,637	186,102	.54%	0.6	*11,000
Portugal	7,877	26,681	34,558	.10%	0.6	* 5,000
Roumania	56,038	—	56,038	.16%	0.3	* 1,000
Russia (October 1, 1929)¶	331,252	—	331,252	.96%	0.2	38,437
Spain	—	184,542	184,542	.54%	0.8	38,209
Sweden	507,325	1,736	509,061	1.47%	8.3	23,310
Switzerland	268,714	—	268,714	.78%	6.7	24,466
Other Places in Europe*	93,255	19,712	112,967	.33%	1.3	5,460
Total	8,795,746	1,239,834	10,035,580	29.07%	1.9	781,190
ASIA:						
British India (March 31, 1930)	21,810	35,091	56,901	.16%	0.02	3,216
China*	90,000	66,000	156,000	.45%	0.04	1,000
Japan (March 31, 1930)	865,516	—	865,516	2.51%	1.4	54,197
Other Places in Asia*	105,795	16,796	122,591	.36%	0.1	9,151
Total	1,083,121	117,887	1,201,008	3.48%	0.1	67,564
AFRICA:						
Egypt	44,834	—	44,834	.13%	0.2	1,610
Union of South Africa#	108,937	—	108,937	.31%	1.4	6,629
Other Places in Africa*	81,023	1,314	82,337	.24%	0.1	8,507
Total	234,794	1,314	236,108	.68%	0.2	16,746
OCEANIA:						
Australia†	505,554	—	505,554	1.46%	7.9	28,854
Dutch East Indies	48,571	4,800	53,371	.15%	0.1	4,170
Hawaii	—	24,366	24,366	.07%	6.6	1,700
New Zealand#	161,041	—	161,041	.47%	10.3	8,500
Philippine Islands	5,832	17,072	22,904	.07%	0.2	1,488
Other Places in Oceania*	3,500	700	4,200	.01%	0.3	300
Total	724,498	46,938	771,436	2.23%	1.0	45,012
TOTAL WORLD	11,117,458	23,409,171	‡ 34,526,629	100.00%	1.8	1,962,409

* Partly Estimated. # March 31, 1930. †June 30, 1929. § January 1, 1929. ¶ U. S. S. R., including Siberia and Associated Republics
‡ Includes approximately 9,060,000 automatic or dial telephones, of which more than 50% are in the United States.

Telephone Development of Large Cities

January 1, 1930

Country and City (or Exchange Area)	Estimated Population (City or Exchange Area)	Number of Telephones	Telephones per 100 Population
ARGENTINA:			
Buenos Aires	2,300,000	149,968	6.5
AUSTRALIA:			
Adelaide	325,000	32,035	9.9
Brisbane	319,000	24,580	7.7
Melbourne	1,018,000	96,181	9.4
Sydney	1,239,000	118,269	9.5
AUSTRIA:			
Graz	164,000	8,719	5.3
Vienna	2,000,000	148,432	7.4
BELGIUM:			
Antwerp	519,000	34,813	6.7
Brussels	938,000	86,635	9.2
Liege	423,000	17,824	4.2
BRAZIL:			
Rio de Janeiro	1,500,000	44,144	2.9
CANADA:			
Montreal	975,000	187,985	19.3
Ottawa	183,000	37,750	20.6
Toronto	710,000	201,419	28.4
CHINA:			
Hong Kong	500,000	11,937	2.4
Nanking	500,000	2,749	0.5
Peiping	1,200,000	12,830	1.1
CUBA:			
Havana	650,000	52,659	8.1
CZECHOSLOVAKIA:			
Prague	732,000	38,869	5.3
DANZIG, FREE CITY OF	305,000	17,248	5.7
DENMARK:			
Copenhagen	790,000	136,528	17.3
FINLAND:			
Helsingfors	234,000	31,180	13.3
FRANCE:			
Bordeaux	264,000	16,207	6.1
Lille	208,000	14,301	6 9
Lyons	588,000	27,435	4.7
Marseilles	672,000	24,140	3.6
Paris	2,955,000	370,308	12.5
GERMANY:			
Berlin	4,330,000	515,175	11.9
Breslau	613,000	42,779	7.0
Cologne	725,000	68,967	9.5
Dresden	630,000	62,393	9.9
Dortmund	535,000	24,756	4.6
Düsseldorf	478,000	46,281	9.7
Essen	645,000	29,291	4.5
Frankfort-on-Main	623,000	65,606	10.5
Hamburg-Altona	1,590,000	173,828	10.9
Hannover	442,000	37,826	8.6
Leipzig	675,000	69,985	10.4
Munich	725,000	75,621	10.4
Nuremburg	494,000	36,924	7.5
Stuttgart	420,000	47,042	11.2
GREAT BRITAIN AND NORTHERN IRELAND (March 31, 1930):			
Belfast	420,000	15,138	3.6
Birmingham	1,115,000	49,805	4.5
Bradford	330,000	17,363	5.3
Bristol	410,000	17,933	4.4
Edinburgh	440,000	27,038	6.1
Glasgow	1,170,000	54,653	4.7
Hull	353,000	16,424	4.7
Leeds	505,000	20,952	4.1
Liverpool	1,165,000	55,091	4.7
London	7,740,000	675,783	8.7
Manchester	1,100,000	59,998	5.5
Newcastle	480,000	18,363	3.8
Nottingham	305,000	14,812	4.9
Portsmouth	290,000	6,993	2.4
Sheffield	515,000	18,049	3.5
Stoke-on-Trent	300,000	6,578	2.2

Telephone Development of Large Cities—(Concluded)
January 1, 1930

Country and City (or Exchange Area)	Estimated Population (City or Exchange Area)	Number of Telephones	Telephones per 100 Population
HUNGARY:			
Budapest	990,000	60,539	6.1
Szeged	127,000	2,560	2.0
IRISH FREE STATE (March 31, 1930):			
Dublin	396,000	15,350	3.9
ITALY:			
Genoa	628,000	22,516	3.6
Milan*	965,000	65,000	6.7
Rome	950,000	40,393	4.3
JAPAN (March 31, 1930):			
Kobe	755,000	28,938	3.8
Kyoto	755,000	33,439	4.4
Nagoya	905,000	27,834	3.1
Osaka	2,409,000	96,044	4.0
Tokio	2,295,000	136,546	6.0
LATVIA (March 31, 1930):			
Riga	378,000	15,745	4.2
MEXICO:			
Mexico City	950,000	47,165	5.0
NETHERLANDS:			
Amsterdam	749,000	47,048	6.3
The Hague	466,000	39,846	8.6
Rotterdam	597,000	40,158	6.7
NEW ZEALAND (March 31, 1930):			
Auckland	198,000	20,558	10.4
NORWAY (June 30, 1929):			
Oslo	250,000	45,353	18.1
PHILIPPINE ISLANDS:			
Manila	370,000	* 16,000	4.3
POLAND:			
Lodz	824,000	11,912	1.4
Warsaw	1,109,000	52,426	4.7
ROUMANIA:			
Bucharest	800,000	15,280	1.9
RUSSIA (October 1, 1929):			
Leningrad	1,840,000	63,104	3.4
Moscow	2,420,000	70,247	2.9
Odessa	435,000	4,886	1.1
SPAIN:			
Barcelona	845,000	32,848	3.9
Madrid	814,000	35,320	4.3
SWEDEN:			
Gothenburg	242,000	35,376	14.6
Malmö	120,000	17,454	14.5
Stockholm	415,000	126,529	30.5
SWITZERLAND:			
Basel	146,000	20,629	14.1
Berne	112,000	17,191	15.3
Geneva	131,000	20,132	15.4
Zurich	222,000	37,864	17.1
UNITED STATES: #			
New York	6,898,600	1,811,410	26.3
Chicago	3,360,000	987,891	29.4
Los Angeles	1,270,000	383,979	30.2
Total of the 8 cities with over 1,000,000 population	19,302,800	4,898,715	25.4
Pittsburgh	976,200	229,135	23.5
Milwaukee	708,100	155,209	21.9
San Francisco	642,300	262,019	40.8
Washington	500,000	163,343	32.7
Total of the 10 cities with 500,000 to 1,000,000 population	6,824,400	1,585,578	23.2
Minneapolis	487,700	131,907	27.0
Seattle	397,500	124,504	31.3
Denver	287,100	89,756	31.3
Omaha	226,200	65,150	28.8
Total of the 32 cities with 200,000 to 500,000 population	9,649,400	2,090,988	21.7
Total of the 50 cities with more than 200,000 population	35,776,600	8,575,281	24.0

* Partly estimated.

There are shown, for purposes of comparison with cities in other countries, the total development of all cities in the United States in certain population groups and the development of certain representative cities within each of such groups.

Telephone and Telegraph Wire of the World, by Countries

January 1, 1930

	Service Operated by (See Note)	Miles of Telephone Wire			Miles of Telegraph Wire		
		Number of Miles	Per Cent of Total World	Per 100 Population	Number of Miles	Per Cent of Total World	Per 100 Population
NORTH AMERICA:							
United States	P.	76,710,000	60.03%	62.4	2,300,000	32.37%	1.9
Canada	P.G.	4,476,213	3.50%	45.4	360,883	5.08%	3.7
Central America	P.G.	53,787	.04%	0.8	21,632	.30%	0.3
Mexico	P.G.	304,467	.24%	1.9	83,834	1.18%	0.5
West Indies:							
Cuba	P.G.	269,827	.21%	7.3	13,594	.19%	0.4
Porto Rico	P.G.	33,585	.03%	2.2	1,077	.02%	0.1
Other W. I. Places*	P.G.	41,472	.03%	0.7	4,606	.07%	0.1
Other No. Am. Places*	P.G.	22,000	.02%	6.2	10,000	.14%	2.8
Total		81,911,351	64.10%	49.0	2,795,626	39.35%	1.7
SOUTH AMERICA:							
Argentina	P.	895,835	.70%	8.0	207,817	2.92%	2.0
Bolivia	P.	5,292	.004%	0.2	4,791	.07%	0.2
Brazil	P.G.	452,411	.35%	1.1	108,587	1.53%	0.3
Chile	P.	134,281	.10%	3.0	39,430	.56%	0.9
Colombia	P.	43,790	.03%	0.5	20,759	.29%	0.2
Ecuador	P.G.	4,745	.004%	0.2	4,874	.07%	0.2
Paraguay	P.G.	6,006	.005%	0.7	2,223	.03%	0.2
Peru	P.	24,585	.02%	0.4	14,449	.20%	0.2
Uruguay	P.	45,327	.04%	2.5	6,465	.09%	0.4
Venezuela	P.G.	48,490	.04%	1.5	6,912	.10%	0.2
Other So. Am. Places	G.	5,287	.004%	1.0	754	.01%	0.1
Total		1,666,049	1.30%	2.0	417,061	5.87%	0.5
EUROPE:							
Austria	G.	656,177	.51%	9.7	46,731	.66%	0.7
Belgium	G.	1,111,514	.87%	13.8	29,814	.42%	0.4
Bulgaria*	G.	55,000	.04%	1.0	8,000	.11%	0.1
Czechoslovakia	P.G.	408,000	.32%	2.8	43,813	.62%	0.3
Denmark (March 31, 1930)	P.G.	930,766	.72%	26.2	7,191	.10%	0.2
Finland	P.G.	277,000	.22%	7.6	10,200	.14%	0.3
France	G.	3,570,000	2.79%	8.6	520,000	7.32%	1.3
Germany	G.	12,845,000	10.05%	20.0	304,000	4.28%	0.5
Great Britain and No. Ireland#	G.	8,390,000	6.57%	18.2	364,000	5.12%	0.8
Greece*	G.	19,000	.02%	0.3	31,000	.44%	0.5
Hungary	G.	361,100	.28%	4.2	51,400	.72%	0.6
Irish Free State#	G.	90,618	.07%	3.0	21,126	.30%	0.7
Italy (June 30, 1930)	P.G.	990,000	.77%	2.4	231,658	3.26%	0.6
Jugo-Slavia*	G.	110,000	.09%	0.7	58,500	.82%	0.4
Latvia (March 31, 1930)	G.	195,000	.15%	10.3	5,000	.07%	0.3
Netherlands	G.	* 686,000	.54%	8.8	28,000	.39%	0.4
Norway (June 30, 1929)	P.G.	532,000	.42%	18.8	29,374	.41%	1.0
Poland	P.G.	623,000	.49%	2.1	56,000	.79%	0.2
Portugal	P.G.	92,000	.07%	1.5	*20,000	.28%	0.3
Roumania	G.	169,795	.13%	0.9	47,518	.67%	0.3
Russia¶	G.	1,000,000	.78%	0.6	500,000	7.04%	0.3
Spain	P.	860,000	.68%	3.8	* 85,000	1.20%	0.4
Sweden	G.	1,170,000	.92%	19.0	51,500	.72%	0.8
Switzerland	G.	779,359	.61%	19.3	21,760	.31%	0.5
Other Places in Europe*	P.G.	305,500	.24%	3.5	30,400	.43%	0.3
Total		36,226,829	28.35%	6.8	2,601,985	36.62%	0.5
ASIA:							
British India#	P.G.	356,462	.28%	0.1	419,664	5.91%	0.1
China*	P.G.	330,000	.26%	0.1	120,000	1.69%	0.03
Japan#	G.	3,040,000	2.38%	4.8	206,000	2.90%	0.3
Other Places in Asia*	P.G.	299,100	.23%	0.2	139,600	1.96%	0.1
Total		4,025,562	3.15%	0.4	885,264	12.46%	0.1
AFRICA:							
Egypt	G.	195,380	.16%	1.0	37,048	.52%	0.2
Union of South Africa#	G.	396,000	.31%	5.0	40,000	.56%	0.5
Other Places in Africa*	P.G.	182,000	.14%	0.2	157,300	2.22%	0.1
Total		773,380	0.61%	0.5	234,348	3.30%	0.2
OCEANIA:							
Australia (June 30, 1929)	G.	2,278,000	1.78%	35.7	110,000	1.55%	1.7
Dutch East Indies	P.G.	218,636	.17%	0.4	20,805	.29%	0.04
Hawaii	P.	74,767	.06%	20.3	0	.00%	0.0
New Zealand#	G.	551,000	.43%	35.2	26,000	.37%	1.7
Philippine Islands	P.G.	46,081	.04%	0.4	10,087	.14%	0.1
Other Places in Oceania*	P.G.	7,600	.006%	0.5	3,900	.05%	0.2
Total		3,176,084	2.49%	4.2	170,792	2.40%	0.2
Total World		127,779,255	100.00%	6.6	7,105,076	100.00%	0.4

Note: Telegraph service is operated by Governments, except in the United States and Canada. In connection with telephone wire, P. indicates telephone service operated by private companies, G. by the Government, and P.G. by both private companies and the Government.
See preceding table.

* Partly estimated. # March 31, 1930. ¶ U. S. S. R., including Siberia and Associated Republics; partly estimated.

Telephone Development of Large and Small Communities—January 1, 1930

Country	Service Operated by (See Note)	Number of Telephones: In Communities of 50,000 Population and Over	Number of Telephones: In Communities of less than 50,000 Population	Telephones per 100 Population: In Communities of 50,000 Population and Over	Telephones per 100 Population: In Communities of less than 50,000 Population
Australia (June 30, 1929)*	G.	289,961	215,593	9.1	6.8
Austria	G.	167,842	54,394	7.2	1.2
Belgium	G.	182,833	76,840	5.6	1.6
Canada	P.G.	713,000	686,986	23.3	10.1
Czechoslovakia	P.G.	64,424	93,283	4.6	0.7
Denmark	P.G.	152,267	189,532	16.4	7.2
France	G.	616,978	439,056	6.9	1.3
Germany	G.	1,948,317	1,233,988	9.2	2.9
Great Britain and No. Ireland#	G.	1,361,000	559,000	5.6	2.6
Japan (March 31, 1930)	G.	507,401	358,115	3.7	0.7
Netherlands	G.	182,106	102,327	6.2	2.1
New Zealand (March 31, 1930)	G.	61,095	99,946	12.0	9.5
Norway	P.G.	63,824	122,964	15.8	5.1
Poland	P.G.	98,957	87,145	2.7	0.3
Sweden	G.	202,899	306,162	†21.0	5.9
Switzerland	G.	118,395	150,319	14.6	4.7
United States	P.	11,106,320	8,961,703*	22.9	12.1

Note: P. indicates telephone service operated by private companies, G. by the Government, and P.G. by both private companies and the Government. See first table.

* Partly estimated.

# March 31, 1930.

† The majority of this development is due to Stockholm.

Telephone Conversations and Telegrams—Year 1929

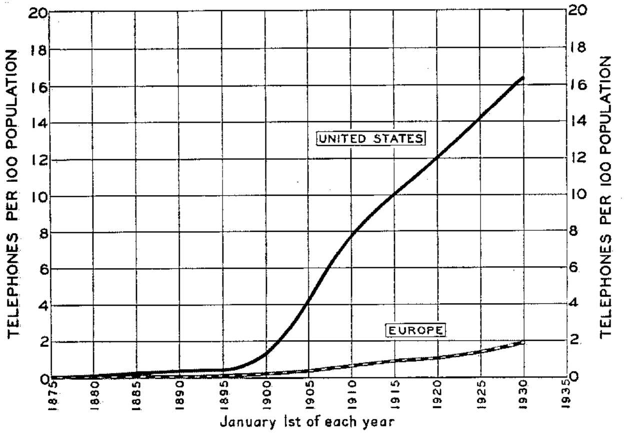
Country	Number of Telephone Conversations	Number of Telegrams	Total Number of Wire Communications	Per Cent of Total Wire Communications: Telephone Conversations	Per Cent of Total Wire Communications: Telegrams	Wire Communications per Capita: Telephone Conversations	Wire Communications per Capita: Telegrams	Wire Communications per Capita: Total
Australia	442,513,000	17,154,000	459,667,000	96.3	3.7	69.9	2.7	72.6
Austria	513,087,000	3,206,000	516,293,000	99.4	0.6	75.8	0.5	76.3
Belgium	203,361,000	5,843,000	209,204,000	97.2	2.8	25.3	0.7	26.0
Canada	2,525,000,000	15,680,000	2,540,680,000	99.4	0.6	257.7	1.6	259.3
Czechoslovakia	263,000,000	5,376,000	268,376,000	98.0	2.0	17.9	0.4	18.3
Denmark	525,630,000	2,118,000	527,748,000	99.6	0.4	148.6	0.6	149.2
France	790,887,000	37,545,000	828,432,000	95.5	4.5	19.1	0.9	20.0
Germany	2,599,000,000	30,200,000	2,629,200,000	98.9	1.1	40.6	0.5	41.1
Great Britain & No. Ireland	1,475,000,000	54,267,000	1,529,267,000	96.5	3.5	32.1	1.2	33.3
Hungary	171,569,000	3,804,000	175,373,000	97.8	2.2	19.9	0.4	20.3
Japan	3,071,000,000	58,721,000	3,129,721,000	98.1	1.9	48.8	0.9	49.7
Latvia	71,000,000	469,000	71,469,000	99.3	0.7	37.5	0.2	37.7
Netherlands	*470,000,000	5,026,000	475,026,000	98.9	1.1	60.4	0.7	61.1
New Zealand	328,626,000	6,943,000	335,569,000	97.9	2.1	212.0	4.5	216.5
Norway	244,000,000	3,450,000	247,450,000	98.6	1.4	86.5	1.2	87.7
Poland	582,833,000	5,823,000	588,656,000	99.0	1.0	19.2	0.2	19.4
Spain	379,000,000	#19,483,000	398,483,000	95.1	4.9	16.7	0.9	17.6
Sweden	773,000,000	4,035,000	777,035,000	99.5	0.5	125.7	0.6	126.3
Switzerland	214,703,000	2,820,000	217,523,000	98.7	1.3	53.2	0.7	53.9
Union of South Africa	204,700,000	5,984,000	210,684,000	97.2	2.8	25.9	0.7	26.6
United States	28,100,000,000	235,000,000	28,335,000,000	99.2	0.8	231.0	1.9	232.9

Note: Telephone conversations represent completed local and toll or long distance messages. Telegrams include inland and outgoing international messages.

* Partly estimated.

# Year 1928.

TELEPHONE DEVELOPMENT IN UNITED STATES AND EUROPE



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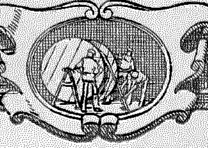

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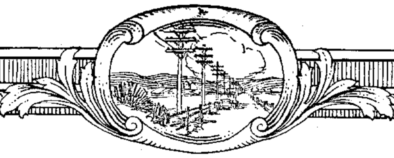

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CONTENTS

PAGE

A LINK WITH OLIVER HEAVISIDE.......................... 53
By Rollo Appleyard

THE SPREAD SIDEBAND SYSTEM ON SHORT WAVE TELEPHONE LINKS.. 60
By L. T. Hinton, A.C.G.I., B.Sc., A.M.I.E.E.

AN EARTHQUAKE DISASTER AND DAMAGES TO THE LONG DISTANCE TELEPHONE CABLE LINE IN JAPAN, 1930...... 67
By Sannosuke Inada

A SYSTEM FOR SIMULTANEOUS TELEPHONY AND TELEGRAPHY OVER LONG DISTANCE SMALL-GAUGE CABLES............ 71
By L. A. Braem

DEVELOPMENTS IN START-STOP TELEGRAPHY—THE NEW CREED PRINTER....................................... 77

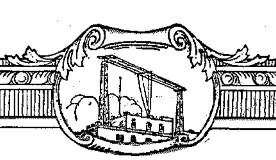
TRANSMISSION TESTING OF SUBSCRIBERS' APPARATUS....... 82
By L. C. Pocock, M.Sc., A.M.I.E.E., A.C.G.I.

ALTERNATIVE TRUNKING FOR TELEPHONE TRAFFIC IN A MULTI-OFFICE AREA.................................. 86

THE UNIVERSAL MOUNTING PLATE...................... 89
By L. H. Webb, B.Sc.

IN MEMORIAM—EDUARD OTTO ZWIETUSCH................ 95

STOCKHOLM-MALMÖ RAILWAY CABLE.................... 96



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67 Broad Street, New York

A Link with Oliver Heaviside

By ROLLO APPLEYARD

SYNOPSIS. *The author has confirmed the fact that Oliver Heaviside was a skilled telegraph operator employed by the Great Northern Telegraph Company of Denmark. Particulars have been collected of the apparatus, speeds, and working arrangements contemporary with Heaviside, for comparison with corresponding equipment today. The author gratefully acknowledges his indebtedness to the Great Northern Company for assistance in this investigation.Examples of modern Creed apparatus are illustrated*

THE obscurity in which the earlier history of Oliver Heaviside has been lost may be, with the progress of time, to some extent dispersed. Since the memoir* concerning him was published in *Electrical Communication*, an important detail has been supplied by information kindly furnished by Mr. F. C. C. Nielsen, who from 1883 to 1915 was the London Manager of the Great Northern Telegraph Company—the Company which, when Heaviside was a young man, operated a submarine cable between England and Denmark, and another submarine cable in the Far East. The circuit to Denmark began with a land line from Newcastle to Newbiggin-on-Sea, which was the landing place of their submarine cable, laid in 1868, to Söndervig in Denmark, a length of about 347 nautical miles, and thence by another land line to Fredericia. The service was between Newcastle-upon-Tyne and Fredericia direct.

At Newcastle in 1870, there were two telegraph operators. One of these was Oliver Heaviside; the other was Mr. Venndt, who for many years was Superintendent in the Great Northern Company's service. Both were very skilled. Heaviside is remembered as having been lonely and silent, but always ready to explain the construction of the apparatus.

About the year 1872, another member of the staff, F. Kolvig, also met Heaviside at Newcastle. A notebook that belonged to Kolvig contains the entry:

> "Heavyside died February, 1925. In
> Great Northern Company, 1870-1874.
> The great mathematical genius."

This entry confirms the required dates, and bridges what was a gap in the story. It is to be observed that Kolvig, who was so closely associated with Oliver, spells the surname in the old form, with a "y."

The possession of these definite particulars encouraged further research; and thanks to the courtesy of the present officials of the Great Northern Telegraph Company, in London and Copenhagen, the records have been searched and the truth is now known. There is only one detail requiring comment: the date of Heaviside's birth appears in the records of the Company as May 18, 1849. The official Register at Somerset House leaves no room for doubt, however, that the actual date was May 18, 1850. From the information now so kindly furnished, it is established that Heaviside was engaged by the Great Northern Telegraph Company at Newcastle-upon-Tyne on February 1, 1870, at a yearly salary of £150, which on February 1, 1871, was increased to £175. As other English operators at the time of their engagement only received about £60 a year, it appears that Heaviside must have possessed special qualifications before his engagement, but of these there is no account.

In the books of the Company his name is spelt "Heavyside," but in his letter asking permission to leave the Company, he signs himself "Heaviside." His service with the Company ceased on May 31, 1874, and the reason given in his letter of resignation is that "I have obtained a situation elsewhere." Here is now available an expression of opinion, dated May 4, 1874, of Heaviside by Mr. H. G. Erichsen, who at that time was the Company's London Manager:

> "Heaviside was a clever worker, but somewhat unruly and especially so since he was informed that he was not given an increase in salary. His application to leave the Company is therefore no great disaster, especially as it will mean a saving."

Those who observed him at close quarters were a little more appreciative of his qualities. In 1873, the Newcastle Superintendent, Mr. Mygind, testified that Heaviside was:

---

* Rollo Appleyard, "Pioneers of Electrical Communication—Oliver Heaviside—VIII," *Electrical Communication*, October, 1928.

> "Very clever and reliable both on Wheatstone and Recorder work. His conduct is exemplary, but in view of his age, high salary, and good qualifications, more interest in the daily work should be expected. His knowledge of the Danish language is fairly good."

One day at Newcastle, he refused to work as a pasting-down clerk, remarking, "I am not a book-binder." The general impression remaining with the Company is that although he was attracted to the technical side of his work, he probably found it difficult to subordinate himself to the daily drudgery of a telegraph station under the old régime.

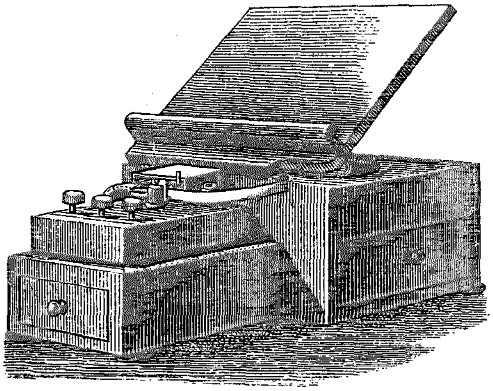

Figure 1—Perforator (Wheatstone's Automatic System).

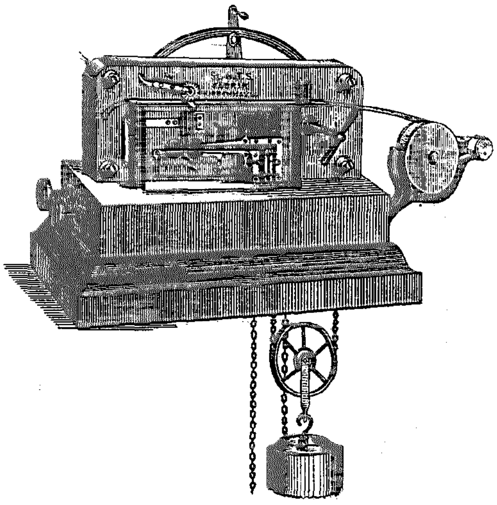

Figure 2—Transmitter (Wheatstone's Automatic System).

Enquiry concerning the account of the apparatus that was operated by Heaviside reveals some instructive particulars.

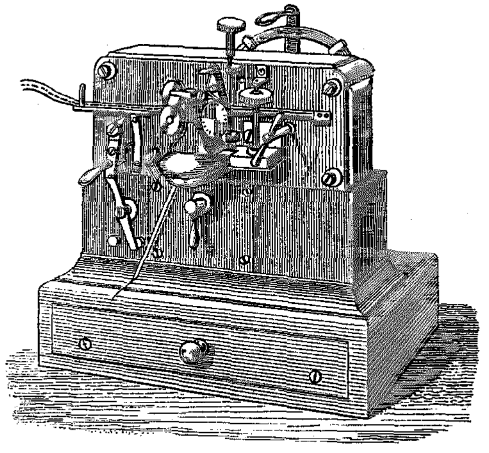

Figure 3—Receiver (Wheatstone's Automatic System).

The Danish cable between the years 1869 and about 1872 or 1873 was worked by a Wheatstone perforator, transmitter, and receiver, (Figures 1, 2, and 3), at twenty-five words a minute. The cable in the Far East was also worked by that system. In early years, the Danish cable, as well as the cable in the Far East, consisted of core insulated with Hooper's Indiarubber, as follows:

	Approximate length in nautical miles	Weight in lbs. per nautical mile	
		Copper	Indiarubber
Newbiggin-Söndervig . .	347	180	180
Woosung-Hong Kong . .	953	300	200

This core was manufactured at Mitcham (Surrey) and was sheathed into cable at Charlton (Kent). The trouble with the Indiarubber was that in a comparatively short time it began to crack at the "wind and water" line. After 1873, gutta-percha cables were used exclusively.

From 1871 to 1873, before Amoy was joined to the cable from Woosung to Hong Kong, the whole length of 953 nautical miles was worked by Wheatstone transmitter and receiver at a speed of from ten to twelve words a minute In 1873, the Newcastle-Fredericia, and the

Fredericia-Libau cables were worked with Sir William Thomson's (Lord Kelvin's) recorder in connection with a Wheatstone transmitter. The speed thereby was increased to from eighty to ninety words a minute. This was highly satisfactory, except that the royalty to be paid for the use of the instrument was regarded as burdensome. Accordingly, in 1876, Lauritzen's undulator, Figure 4, was adopted. The speed with that instrument was at first from fifty to sixty words a minute but, with a later form (Figure 5), a speed of one hundred words a minute was attained. The undulator was also used at Vladivostok, Shanghai, and Hong Kong.

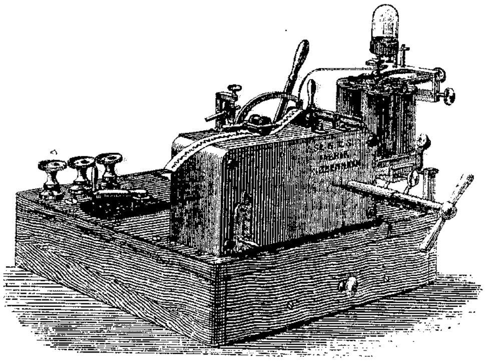

Figure 4—Undulator (Lauritzen's Undulating Inkwriter).

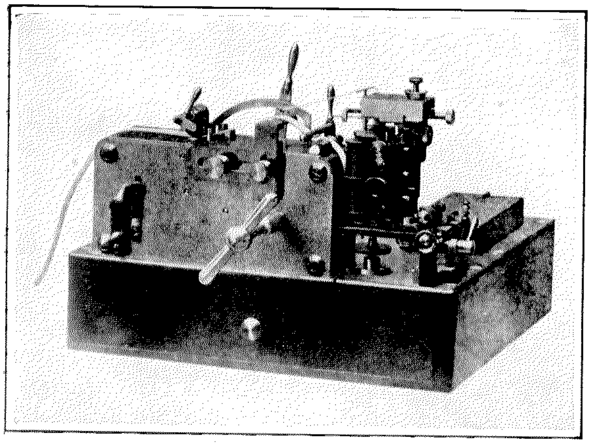

Figure 5—Undulator With Clockwork Driven by Spring.

A Wheatstone transmitter was then constructed to send reversed signals, and was introduced on the cables in the Far East. To produce these reversed signals, a double current key was used, whereby positive marking currents and negative spacing currents were sent to line.

With speeds of one hundred words a minute, the new difficulty arose that the clerks could not write down the received messages fast enough to keep pace with the instrument. Moreover, at speeds over twenty to thirty words a minute, it was necessary to employ more than one "writer" to keep pace with the receiving instrument. The "gummer," Figure 7, was therefore introduced. This enabled the received "slip" to be dealt with in convenient lengths, so that the writing could be done by a division of labour. A further improvement in the undulator was next introduced, Figure 6, whereby the instrument was motor-driven.

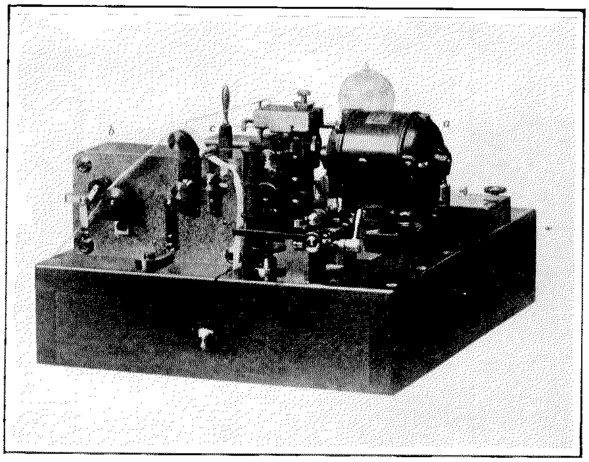

Figure 6—Motor-driven Undulator.

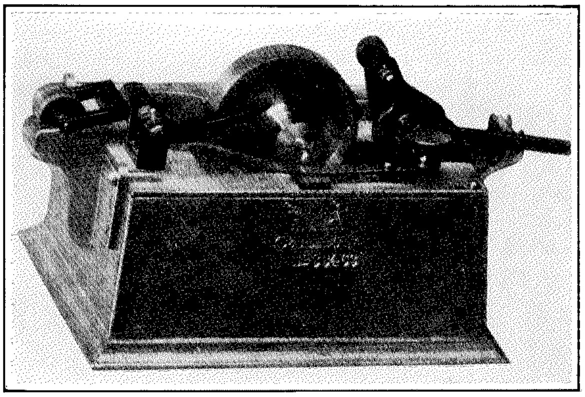

Figure 7—Gummer. (Machine for Gumming the Slip.)

It is appropriate to recall a remark made by Mr. F. C. C. Nielsen on the occasion of a dinner given to the staffs of the various cable companies in London, on January 9, 1909—just fifty years after the laying of the first Atlantic cable. Mr. Nielsen alluded to the marvellous development of cable enterprise from its inception to the present day, and reminded them that it was just over fifty years since the laying of the first Atlantic cable, a magnificent performance, although as might have been anticipated, the cable, was not, for some time, in full working order. Mr. Nielsen's recollection did not take him so far back as that—only 39 years, in fact. He said:

> "On looking back to those early days of the cable enterprise, I think the Anglo was already a big company; the Eastern did not exist, but only some smaller companies which later on were to become the Eastern. Then came the Great Northern Company. The Danes looked across to England, and the English looked across to Denmark. It would not do to allow all messages to go via Germany, and so the question arose, 'Who should do the work?'"

As it turned out, their Company, the Great Northern, accomplished the task. Mr. Nielsen went on:

> "Thirty-nine years ago I had the pleasure of joining the Company, and was initiated in the mysteries of telegraphy."

He then spoke of the marvellous improvements due to the introduction of the Wheatstone instrument, which was worked in those days in Newcastle by Mr. Oliver Heaviside, and their own esteemed Superintendent, Mr. Venndt. He added:

> "Of course, fresh developments have taken place since then, and I think the time will come very soon when there will be no telegraph operators left. Thanks to the genius of Mr. Creed, we have got instruments far in advance of those at present in use. We shall come to the time when the instruments will be perfectly automatic. You will be able to send anything you like; in fact, the customer will enter the station and be asked to punch his own messages. He will then take the slip to the counter-clerk, who will measure it out at the price of 11¾ d. per yard—with reduction on quantities and special sale prices."

To complete the story, it may be observed that, from data kindly furnished by the Great Northern Telegraph Company of Denmark, it appears that today the normal Duplex speeds on the various sections of their London-Shanghai circuits are as follows, in words a minute:

London-Newcastle	90
Newcastle-Leningrad	90
Leningrad-Irkutsk (on two lines)	60
Irkutsk-Nagasaki (via Vladivostok)	60
Nagasaki-Shanghai (on both cables)	100

Between Irkutsk and Nagasaki there is another circuit which is worked thus:

Irkutsk-Vladivostok	50
Vladivostok-Nagasaki	50

There are Creed-Receivers at London, Newcastle, Leningrad, Irkutsk, Nagasaki, and Shanghai. The secondary circuit between Irkutsk and Nagasaki is worked with Creed-Receivers at Vladivostok.

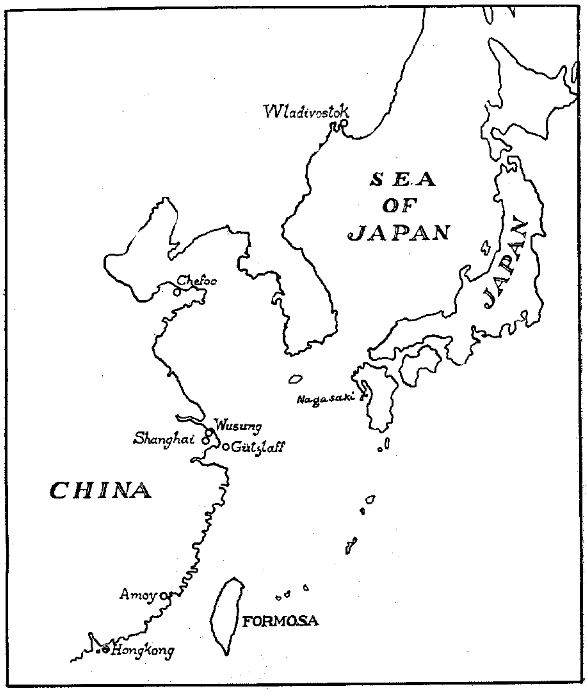

Figure 8—Map of China Seas.

Briefly, the whole system today from London through Nagasaki to Shanghai is operated by Creed perforating receivers, and the messages are printed automatically at the terminal stations by the Creed printer. The average time required for transmission is approximately:

To London from Shanghai	27 minutes
" " " Tientsin	40 "
" " " Kobe	53 "
" Shanghai from London	29 "
" " " Hamburg	39 "

To show how fully Mr. Nielsen's prophecy has been justified by events, it is helpful to trace the growth of the Creed apparatus since 1909. During the war, instrument makers were in many instances diverted to munition work. In 1918, when peace conditions invited a return to normal productions, it was a difficult task to establish again the required standard of workmanship for the telegraphic equipment, on an economic basis. Undaunted by these adverse circumstances, Mr. Creed met them by redesigning his apparatus. He constructed a keyboard perforator, Figure 9, for preparing the Wheatstone slip, a Morse transmitter, Figure 10, a receiving perforator, Figure 11, for reproducing it, and a printer, Figure 12, for printing from the reproduced Wheatstone slip. These machines utilised cams for all the relative movements, and they avoided the use of compressed air that characterized his former designs. The new machines were found to be even more efficient, more durable, and simpler than those that preceded them.

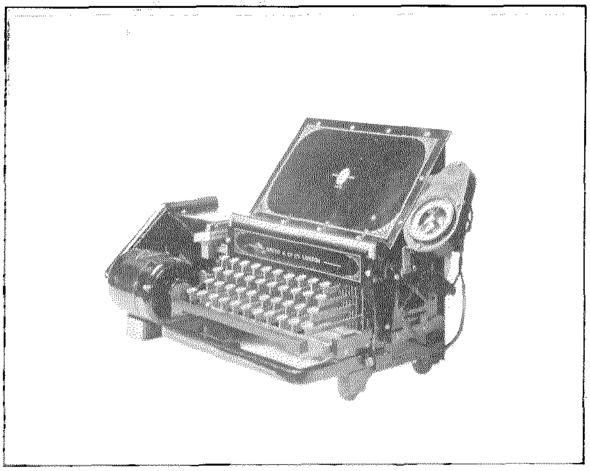

Figure 9—Morse Keyboard Perforator.

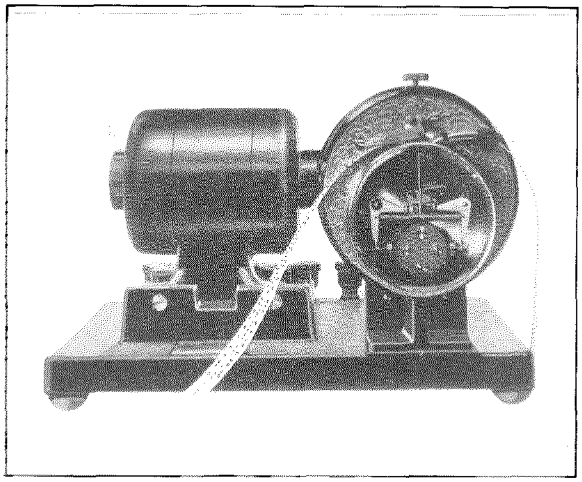

Figure 10—Morse Transmitter.

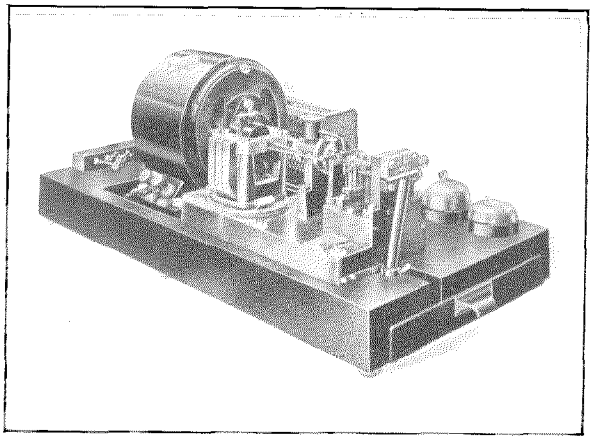

Figure 11—Morse Receiving Reperforator.

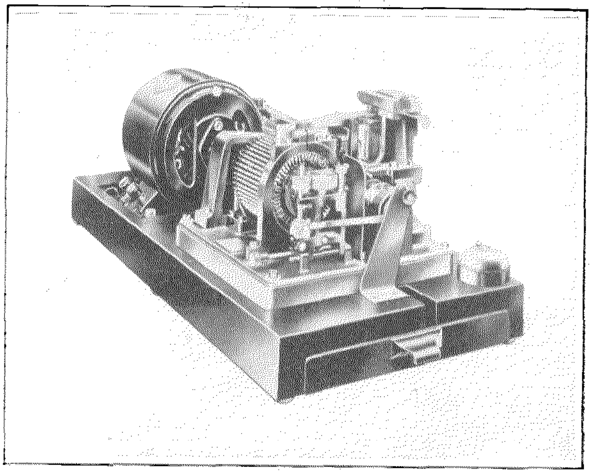

Figure 12—Morse Tape Printer.

The advance, however, did not stop there. About six years ago, Mr. Creed became convinced that the Morse apparatus would fall short of the requirements of commercial telegraphy. He therefore began experiments with 5-unit apparatus, and endeavoured to produce a simpler and more economical machine than those that then existed. Previous experience with the Morse apparatus was skillfully applied, and the result is the present wonderful equipment.

In 1925, the Creed establishment acquired Mr. Donald Murray's 5-unit keyboard perforator, electro-magnetically actuated, and the whole of the Murray multiplex system machines, including the curved code bar, for England and several European countries. The establishment also had the benefit of Mr. Murray's valuable advice. Among the machines resulting from this combination of effort by those men of genius and skill are the present-day Murray Keyboard Perforator, Figure 13, and Creed Keyboard Perforator Transmitter, Figure 14, the Creed Automatic Transmitter, Figure 15, and the Start-Stop Tape-Printer, Figure 16. These form a complete system suitable for long single-channel circuits working upon an automatic tape-transmission basis. In the case of long heavy traffic circuits, and some medium traffic circuits, printing on tape is found more advantageous than printing in page, owing to the greater convenience in cutting out errors due to line faults.

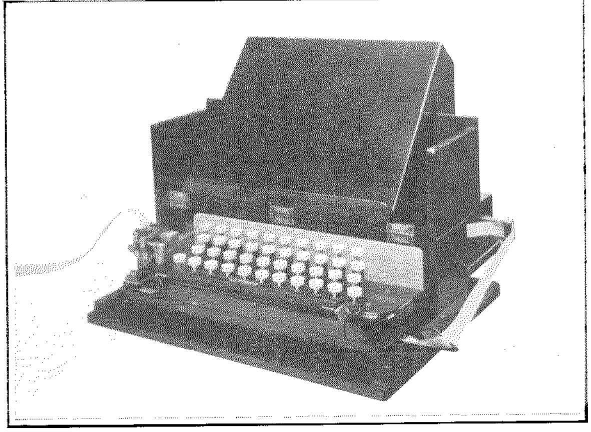

Figure 13—Murray Keyboard Perforator.

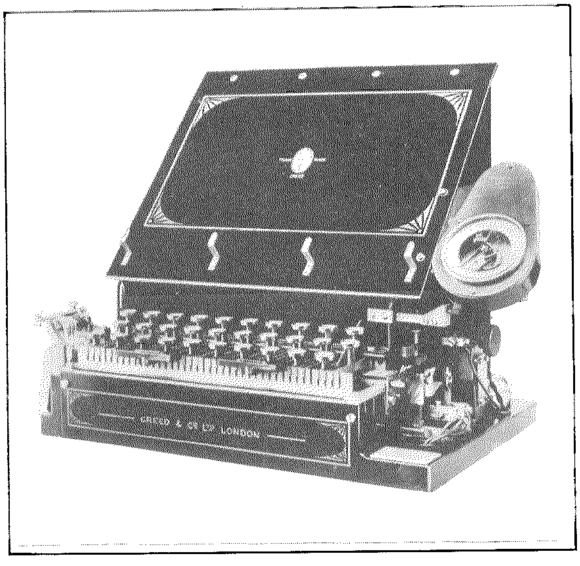

Figure 14—Teleprinter Keyboard Transmitter Perforator.

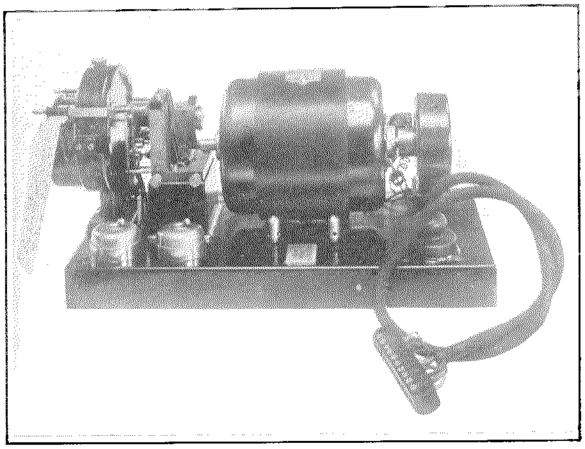

Figure 15—Teleprinter Auto-transmitter.

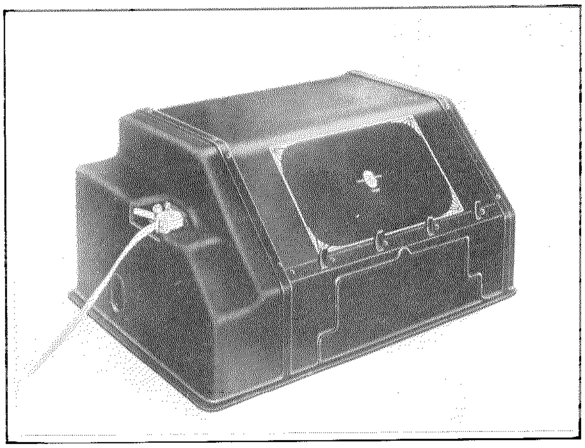

Figure 16—Tape Teleprinter No. 3-R.

For circuits where line-time is of less importance than operator costs, another set of apparatus has been developed consisting of a Keyboard Transmitter and a Printing Receiver, combined in one instrument, Figure 17. In this case, a similar instrument is used at each end of the line, and is adapted to work either simplex or duplex. When working simplex, the receiving section of the instrument is automatically connected to the line so as to provide a record of the message sent. When working duplex, no record is kept, and the receiving section of the instrument is used for reception only, and works independently of the transmitter. Both the transmitting and the receiving sections of the combined instrument are actuated by the same motor. The motors at the two ends of the line are, by means of a very simple and trustworthy device, made to work in effective synchronism. The combined instruments are made in two forms, according to requirements, i.e., the tape-printing and the page-printing models, and both are usually worked at about 60 words a minute, but somewhat higher speeds can be attained if desired. It may be observed that in Start-Stop practice, synchronism is not really necessary, i.e., only isochronism is essential.

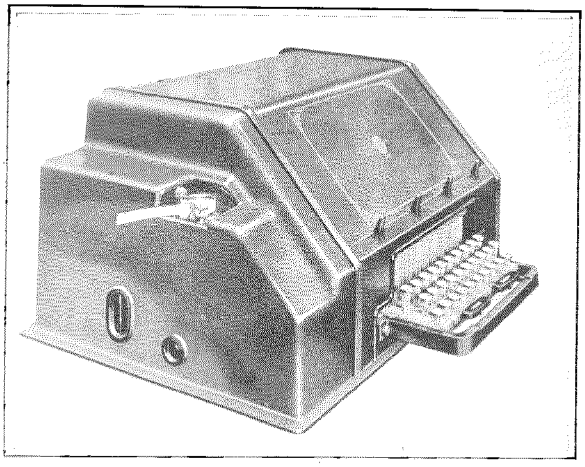
Figure 17—Tape Teleprinter No. 3-A.

The Spread Sideband System on Short Wave Telephone Links

By L. T. HINTON, A.C.G.I., B.Sc., A.M.I.E.E.

International Telephone and Telegraph Laboratories, Incorporated

DURING early tests on wavelengths lying below 100 metres several new phenomena were noted which had not been present in work on the longer wavelengths.

In particular, attention was drawn to "fading"* which was a general term adopted to express a change in attenuation of the ether path. Further investigation led to the separation of this term into three distinct parts:—(a) Diurnal variation of field; (b) general fading; and (c) selective fading.

Research in this field has been concentrated on the development of means for overcoming the detrimental effects of these types of fading on the reliability of communication channels. Since it has been found experimentally that the effects of the types of fading on communication efficiency are entirely different, it will be best to consider them separately, and to show methods by which the effect of each source of trouble can be reduced or eliminated.

Diurnal Variation

Diurnal variation is of course present on all frequencies, and is due to the fact that the transmission equivalent or attenuation of the ether path is not a fixed quantity. Approximate values of this attenuation can be calculated for certain distances and wavelengths, but even these are not very reliable for short wave transmission.

The field strength of a given frequency, when measured at a given point, with a constant transmitted power will vary during twenty-four hours from a value so low that no known receiver can detect it, to values as high as 50 db. above one microvolt per metre. In Figure 1 there is shown a typical 24-hour run taken on 19,030 kilocycles (15.75 metres) at Buenos Aires with the transmitter located at Madrid, Spain.

This curve illustrates admirably the very great changes in actual attenuation which take place. The values which are plotted on the curve are averages of the received field taken over about three minutes.

General Fading

This term is used to cover the fluctuation of the whole field from minute to minute during the period when the field is at sufficient strength to be received.

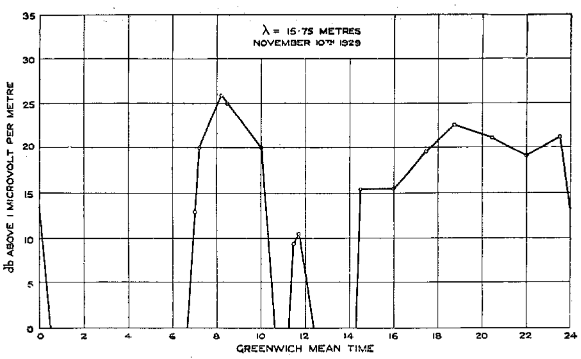

Fig. 1—Field strength of Madrid (E.H.Y.) measured at Buenos Aires.

It is characterised by an attenuation change of the carrier and both sidebands simultaneously and to the same extent, and may be considered as a ripple on the smooth curve shown in Figure 1.

It will be apparent that this change in attenuation can be considered together with the diurnal variation, and that both can be compensated by means of corresponding changes in the receiver gain. In commercial receivers this control is partly manual and partly automatic. The receiver operator sets his manual control so that the level of the received signal is approximately correct, and then cuts his automatic gain control system in circuit.

A typical automatic gain control circuit is illustrated in Figure 2. The direct current output of an auxiliary detector is impressed across a high resistance, which in turn is connected into the grid biassing circuit of the first demodulator tube of the super-heterodyne receiver.

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* R. K. Potter, "Transmission Characteristics of Short Wave Telephone Links," I.R.E., April, 1930.

It will be seen that when the signal rises, the current flowing through the high resistance will increase, and thus produce an increased voltage drop across it. This in turn is used to decrease the sensitivity of the first demodulator, and thus to lower the efficiency of the receiver. By this means the output signal level from the receiver remains substantially constant over the period during which a given wavelength can be received.

With the receiver used for commercial telephone traffic on the Buenos Aires to Madrid radio link the automatic gain control will hold the total detected signal to a constant level ± 2 db. over a range of received signal variation of 40 db.

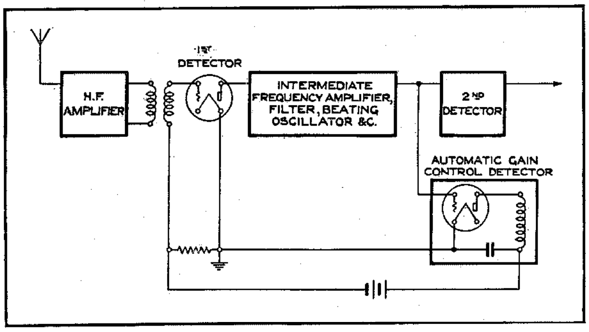

1ST DETECTOR
H.F. AMPLIFIER
INTERMEDIATE FREQUENCY AMPLIFIER, FILTER, BEATING OSCILLATOR &C.
2ND DETECTOR
AUTOMATIC GAIN CONTROL DETECTOR

Fig. 2—Schematic of automatic gain control circuit.

A discussion of the factor in the received signal which achieves this result, analysing the total detected signal into its component parts and explaining the function of each part, is presented in a later section of this paper.

Selective Fading

The third type of fading, usually known as selective fading, is rapid and deep in its action. This selective fading is caused by an interference pattern of two or more reflected waves, which reach the receiver after reflection from the ionised strata in the upper atmosphere known as the Heaviside Layer. The exact mechanism which causes the interference pattern is still somewhat obscure, but its effect can be understood from a simple assumption of two reflected waves reaching the receiver by means of two independent paths whose relative lengths are changing slightly all the time. The fading is of course due to the changing phase relations of the two paths. Such phase differences can result in a change of equivalent of a single wave from about + 3 db. when two waves are in phase, to an almost total loss when they are 180 degrees out of phase.

The rate at which this fading in and out of phase changes during the period of reception of a given wavelength is somewhat similar to the change of attenuation.

In Figure 3 this fade rate is shown as measured on a volume indicator. The transmitter sends a continuous steady tone, and one fade is counted every time the received volume drops more than about 15 db. below the normal received tone level. It will be seen that this type of fading seems never to be entirely absent, and at times reaches a frequency of some hundreds of fades per minute. In actual practice periods have been noticed when the rate of fading is too rapid for accurate counting.

If a comparison is made between Figures 1 and 3 it can be generally stated that while the field is steady the fading rate is steady, and that when the field is coming in or going out the rate of fade becomes very erratic.

It is now necessary to consider the effect of this type of fading on received speech. It will be apparent that for the very deep fades, when the received field is practically non-existent, the received speech will give the effect of being chopped in much the same way as would occur in a badly adjusted voice-operated echo-suppressing system.

It has been noticed also that before the fading becomes so bad that actual chopping takes place, speech assumes a bad quality which can best be described as sounding like an overloaded amplifier. Experimental curves taken on the New York-London circuit show that of two frequencies lying close to one another, one will fade while the other remains unaffected. Hence, if we consider a carrier and two sidebands which will occupy a total band width of 6,000 cycles, it will be seen that fades can occur: (a) in either or both sidebands simultaneously; (b) in one sideband and the carrier at the same time; or (c) in the

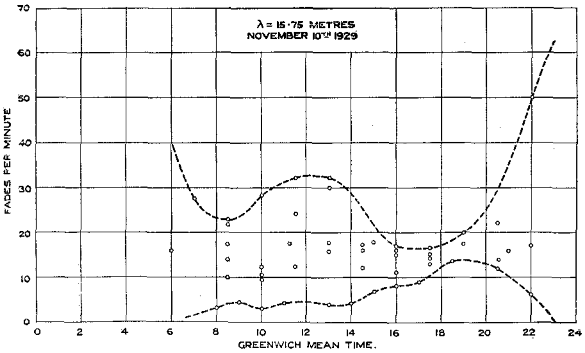


Fig. 3—Fading rate of Madrid (E.H.Y.) measured at Buenos Aires.

carrier alone, leaving the sidebands untouched.

Further it must be emphasized that the width of fade-band is generally so small that only about 100 to 200 cycles are affected at one time. It seems, however, that the movement of the cut-out portions across the spectrum is entirely random, so that there does not appear to be any logical solution in the direction of evening-up the attenuation.

In order fully to appreciate the effect of fading on the quality of received speech it is necessary to investigate mathematically its effect on a signal composed of a carrier modulated with a single frequency. It will be assumed in the discussion that the sideband frequencies lie sufficiently far from the carrier to be affected independently by the fading.

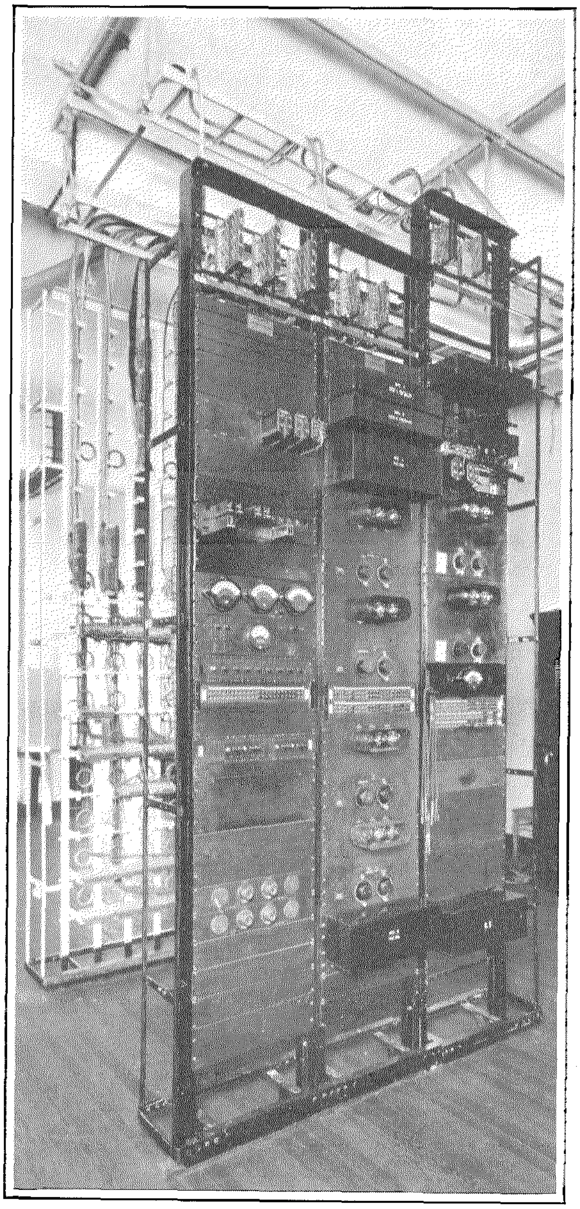
The modulation system used on telephone transmitters produces a carrier frequency and two sidebands. One sideband corresponds in frequency to the carrier frequency plus the voice frequency, and the other to the carrier frequency minus the voice frequency. Let us assume that the carrier is modulated by a single pure tone sin wt, with the result that the modulated wave can be treated on the air as three independent frequencies. Let us call these three frequencies:

$$\begin{aligned} \text{Carrier} &= c \sin rt \\ \text{Upper Sideband} &= a (\sin (r+w)\, t) = a \sin pt. \\ \text{Lower Sideband} &= a \sin (r - w)\, t = a \sin qt. \end{aligned}$$

At the receiving end various systems of detection may be used, but the actual system is immaterial, since at the final detector stage three frequencies appear which have to be detected in order to obtain an intelligible signal. The general formula for a vacuum tube when used as an anode bend detector is $(A_1 e + A_2 e^2)$ and if we apply the three frequencies given above to such a device, the operation of detection can be expressed mathematically as follows:

$$\text{Signal} = A_1 (a \sin pt + a \sin qt + c \sin rt) + A_2 (a \sin pt + a \sin qt + c \sin rt)^2 \dots\dots\dots\dots (1).$$

The first term can be neglected for the purposes



Spread Sideband Equipment installed at Buenos Aires for use on the radio link between Buenos Aires and Madrid.

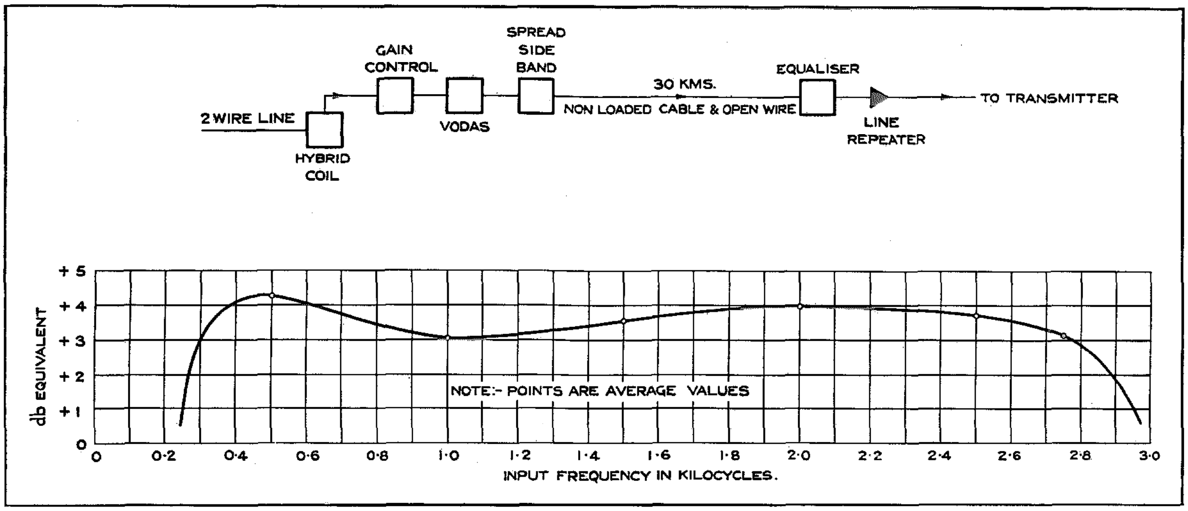


Fig. 4—Attenuation characteristic of transmitting circuit.

of detection since it represents the original three frequencies with a change in amplitude. This term is present due to the fact that the vacuum tube characteristics, as shown above, are not a pure square law. This term is, of course, lost in the filter circuits associated with the output of the detector.

Dealing with the second term, and expanding it, we have:

$$A_2\,(a^2 \sin^2 pt + a^2 \sin^2 qt + c^2 \sin^2 rt + 2a^2 \sin pt \sin qt + 2ac \sin pt \sin rt + 2ac \sin qt \sin rt) = A_2\left(a^2 + \frac{c^2}{2}\right) - A_2\left(\frac{a^2}{2}\cos 2\,pt + \frac{a^2}{2}\cos 2\,qt + \frac{c^2}{2}\cos 2\,rt\right) - A_2\Big[a^2 \cos (p+q)t + ac \cos (p+r)\,t + ac \cos (q+r)t\Big] + A_2\Big[a^2 \cos (p-q)\,t + ac \cos (r-p)t + ac \cos (q-r)t\Big] \ldots\ldots\ldots (2).$$

The first term represents direct current, and it is by means of variations in this term that the automatic gain control operates as described above.

Now the automatic gain control functions on the total detected signal only, and cannot discriminate between the relative amplitudes of the carrier and sidebands at any instant. On the other hand the subscriber is not interested in the steadiness of the total received signal, but in the steadiness of the detected sidebands which carry the intelligibility. It will be seen, therefore, that the gain control acts only to keep constant a quantity which depends on the sum of the sideband and carrier amplitude, and cannot therefore be affected by a change of relationship between their respective amplitudes.

The second and third terms represent double frequencies and frequency sums of the original frequencies, and therefore lie beyond the audible range.

These terms are likewise removed from the signal by means of the same filters which dealt with the first term of the original equation.

We are, therefore, left with the last term of the equation, which, by means of differences, represents the intelligible signal. Separating this term, therefore, we get:

$$A_2\Big[ac\,(\cos (r-p)\,t + \cos (q-r)\,t) + a^2 \cos (p-q)t\Big] \ldots\ldots\ldots (3).$$

The frequency $(r-p)t$ is given by the difference between the carrier and the lower sideband, and is the same as $(q-r)t$ which is given by the difference between the upper sideband and the carrier. Hence we can write equation (3) in the following form:

$$A_2\left[2\,ac\cos(r-p)\,t+a^2\cos(p-q)\,t\right]\ldots\ldots(4).$$

Referring to our original assumption of the three frequencies involved in the ether wave, it follows that the difference $(r-p)\,t$ is equal to wt which is the original pure tone in the voice range, and that the difference $(p-q)\,t$ is equal to 2 wt which is a second harmonic of the original pure tone. Hence, if the original voice frequency was sin wt, we can write the above expression as:

$$2A_2\,ac\cos wt+A_2\,a^2\cos 2\,wt\ldots\ldots\ldots\ldots(5).$$

If the conditions are perfectly stable the amplitude A_2a^2 is small compared to $2A_2$ ac, except when the percentage modulation on peaks of speech approaches 100% when A_2a^2 tends to approach half the value of $2A_2$ ac.

If these two terms are now considered under fading conditions it will be seen that the harmonic term, which is normally small in comparison with the single frequency term, will only become prominent when the carrier fades. This will be apparent, since if the sideband amplitude "a" decreases, the harmonic distortion will become less than normal, both terms being affected by the change. If the carrier amplitude "c" decreases, however, the true signal term only is affected and the harmonic distortion becomes abnormally great, and under extreme circumstances has been observed to be greater than the single frequency amplitude.

From the above explanation it will readily be understood that in operation selective fading produces the same type of distortion as an overloaded amplifier, and is sometimes referred to as "harmonic distortion."

It is now necessary to consider this distortion effect on any of the known "privacy systems" such as are used on radio-telephone channels.

We will consider a privacy system in which an original speech frequency, sin wt, is by known means placed in some other position in the speech band before being transmitted. Purely as an example we will assume that a frequency, sin xt, is subtracted from it, so that it goes out on the ether as sin $(w-x)$ t.

Now at the receiving end we shall get a component, sin $(w-x)t$ and a harmonic component sin $(2w-2x)t$, to both of which components sin xt must be added in order to obtain our original speech frequency, sin wt. This addition will, therefore, give us sin wt and sin $(2w-x)t$.

To make this clearer let us take a numerical example:

Let sin wt = 1,900 cycles per sec.
sin xt = 1,000 cycles per sec.
∴ sin $(w-x)t$ = 900 cycles per sec.

Then at the output of the receiver we shall have:

sin $(w-x)t$ = 900 cycles per sec.
and sin $(2w-2x)t$ = 1,800 cycles per sec.

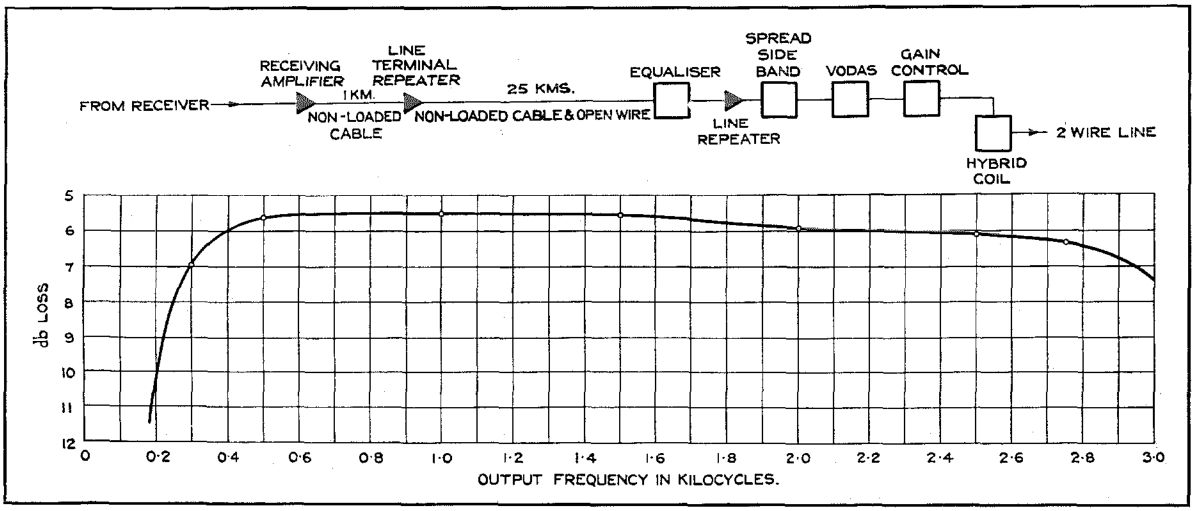


Fig. 5—Attenuation characteristic of receiving circuit.

Now after passing through the receive half of the privacy device, which will add sin xt to whatever comes to it, we get:

$$\sin (w-x)t + \sin xt = 900 + 1{,}000 = 1{,}900 \text{ cycles per sec.}$$

$$\sin (2w-2x)t + \sin xt = 1{,}800 + 1{,}000 = 2{,}800 \text{ cycles per sec.}$$

It will, therefore, be seen that selective fading, when applied to a system using privacy, will result in the production of spurious frequencies bearing no harmonic relation to the true signal. This type of distortion is very much worse than pure harmonic generation, and can very easily render the speech quite unintelligible.

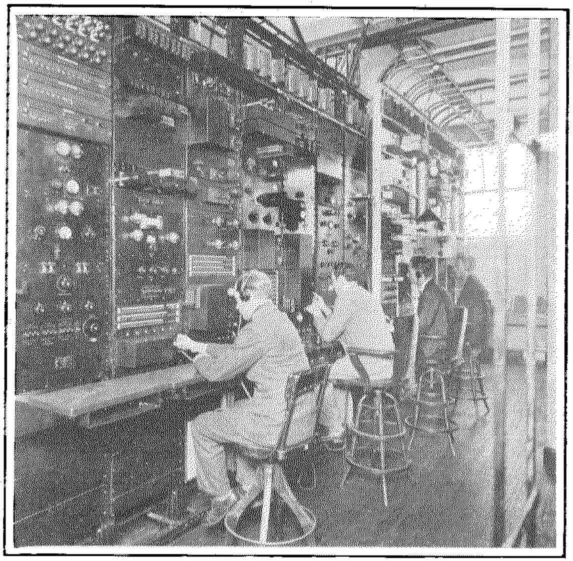
A remedy for this type of distortion would be found if it were possible to separate the spurious frequencies from the true frequencies, and an inspection of equation (5) suggests a line of attack which leads to the Spread Sideband System* which is in successful commercial operation on the Buenos Aires-Madrid radio link.

The operation of this system can easily be understood if we add a fixed frequency, sin Wt, to the original sin wt which is transmitted. Equation (5) then becomes:

$$2A_2 ac \cos (w+W)\,t + A_2a^2 \cos (2w+2W)\,t \;\ldots\ldots\ldots\ldots (6).$$

Now if it is desired to transmit a band of frequencies from zero to wt, and Wt is made equal to the highest value of wt, then by inspection of equation (6) it will be seen that the single frequency term lies between wt and 2wt for all values of w, and the harmonic term between 2wt and 4wt. The single frequency term can then be separated from the double frequency term by filters, and the frequency Wt is subtracted from it, thus leaving the band lying between zero and wt as originally required.

A numerical example will probably make the system much clearer. Let us assume that we wish to transmit a band of frequencies for speech from 250 to 2,500 cycles per sec. Then, before we reach the transmitter, we add to this band a fixed frequency of 2,500 cycles with the result that there is an empty space next to the carrier, and the speech lies between 2,750 cycles and 5,000 cycles per sec. At the output of the receiver, therefore, the results of detection are:



Technical operators' positions at Buenos Aires, showing (left to right) Temporary European, Permanent European, and New York.

$$\left\{(2A_2 ac \cos (w+W)t\right\}\begin{array}{l} w = 2{,}500 \\ \;\;\, = K_1 \text{ (2,750 cycles to} \\ w = 250 \quad \text{5,000 cycles)} \end{array}$$

$$+\left\{(A_2a^2 \cos (2w+2W)t\right\}\begin{array}{l} w = 2{,}500 \\ \;\;\, = K_2 \text{ (5,500 cycles to} \\ w = 250 \quad \text{10,000 cycles).} \end{array}$$

The spurious frequencies of the second term can, therefore, be separated by a low-pass filter with a cut-off of, say, 5,200 cycles per second, leaving only the first term of the results of detection.

At the receiving end terminal office we will subtract the fixed frequency of 2,500 cycles originally added, and the first term then becomes:

$$K_1 \text{ (250 cycles to 2,500 cycles)}$$

which is the original speech band which we wished to transmit.

It will be appreciated that speech sounds do not consist of single frequencies, and that intermodulation between component frequencies of a signal is present when the Spread Sideband System is not in use.

When the sidebands are displaced the products of intermodulation between frequencies within either sideband fall outside the displaced band after detection, so that this source of distortion, although small, is also removed.

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* British Patent Application 156 of 1930.

By an extension of the principles enumerated above, a number of sidebands can be placed on one carrier in such relative positions to each other and to the carrier that "harmonic distortion" is eliminated, as well as crosstalk between the various communication channels.

Overall Characteristics

The overall attenuation frequency characteristics of the transmit and receive side are interesting because of the equalisation which is necessary in order to get a flat characteristic. Both legs of the circuit contain delay networks, spread sideband privacy equipment and connecting lines, the latter being made up partially of non-loaded cable and partially of open-wire lines.

Figure 4 shows the overall characteristics taken from the two-wire side of the terminating set at the central office to the input of the transmitter. Figure 5 shows the receive side measured from the output of the second detector in the receiver itself to the two-wire side of the terminating set.

It will be seen from the drawings that the whole of the spread sideband equipment, together with the VODAS equipment* has been so equalised that an essentially flat characteristic is obtained between 300 and 2,800 cycles per second.

The author wishes to thank members of the staffs of the C.T.N.E., the C.I.R.A., and the I. T. & T. Laboratories for their helpful and active co-operation in the tests.

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* *Electrical Communication*, Vol. 8, No. 4.

An Earthquake Disaster and Damages to the Long Distance Telephone Cable Line in Japan, 1930

By SANNOSUKE INADA

Director General of Telegraph and Telephone Engineering, Department of Communications, Japan

AT dawn of November 26th, 1930, there occurred a severe earthquake in the northern end of the Izu Peninsula and the Hakone range which are well known for their picturesque scenery and their hot springs.

This quake is reported to have been caused by a chasm slip which took place in the Tanna basin, an extensive valley, and which was the centre of the disturbance. The disaster spread over an area having a radius of 50 to 60 km., extending to Kozu in the east, Shizuoka in the west, Gotemba in the north, and to Shimoda in the south (see Figure 1). The seismic width of the earthquake felt in the Atami district (on the Izu Peninsula) is calculated to have been 100 mm. The severity of the quake, and the time it lasted, are reported to have greatly exceeded the great Kanto Earthquake of 1923.

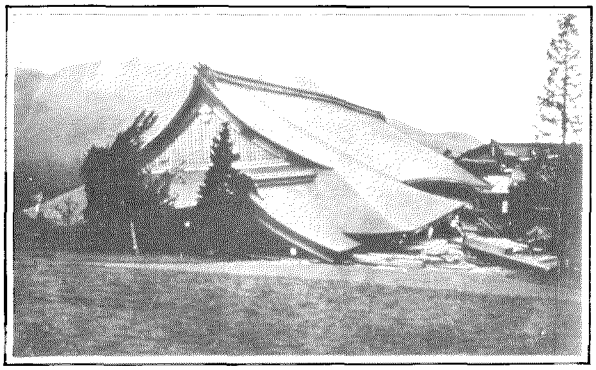

Figure 2—The Collapse of the Hakone Palace.

According to an announcement made by the respective prefectural authorities, the casualties and the number of houses damaged were as follows:

Towns and villages affected	42
Number of people killed	250
Number of people injured	143
Houses demolished	1,530
Houses damaged	4,632

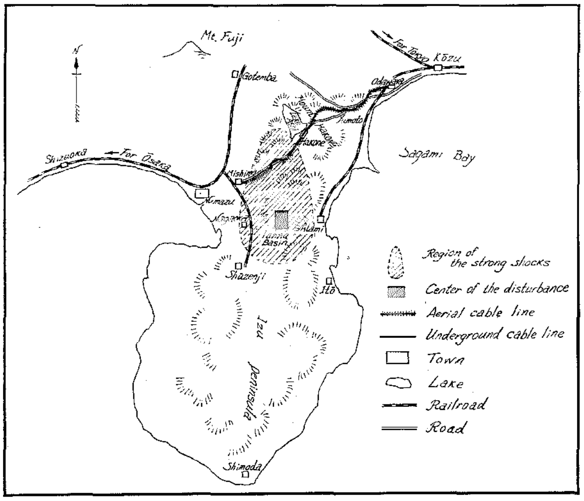

Figure 1—The Region of Shocks and the Route of the Long Distance Telephone Cable Line.

Although the zone affected by severe shock was comparatively limited and the damage caused by fire following the earthquake was not very great, the total loss sustained, including that to forests and cultivated fields, amounted to an estimated cost as large as 20,000,000 yen. In Figure 2 is shown the collapse of the Hakone Palace and, in Figure 3, rocks blocking one of the main roads. Damages to the public telephone and telegraph plants affected 37 telegraph circuits, 147 toll telephone circuits, 2,100 telephone subscribers and six post offices, four of which were entirely demolished, one partially destroyed and one flooded. Injury to the telegraph and telephone equipment in these six offices was such that the service was completely interrupted. Among the communication lines which suffered, the 184 pair long distance telephone cable and open wire telegraph lines were the worst affected with consequent trouble and confusion in every line of business.

In order to provide relief after such a disaster, rapid restoration of the means of communication is most necessary, especially in the case of long distance communication lines.

Within the zone of the most violent shocks, the long distance Tokyo-Osaka telephone cable and the main open wire telegraph line run through the Hakone Mountains from Odawara on the north-east of the range to Mishima to the south-west for about 32 km. The cable was laid in 1925 soon after the great earthquake of 1923; aerial cable construction was chosen along most of the route except when passing through villages in order to avoid damage such as that inflicted on underground cables in the last disaster. The section between Odawara and Mishima consisted of 24.3 km. of aerial cable, 3.7 km. duct cable, and 3.9 km. of armoured cable. Most of the route followed by this cable is very mountainous, containing many precipitous cliffs and valleys, owing to the fact that the Hakone range was formed by a series of volcanic eruptions within what is now a larger and older crater. Since the roads are built along such precipices and are exposed to the destructive effects of landslides, often due to floods or earthquakes, it was decided that the ridges were the most practical and the safest route for the long distance cable. Much effort was expended during the course of construction in the transportation of cable reels and loading cases, as there are no facilities for lifting such heavy loads to the tops of the ridges.

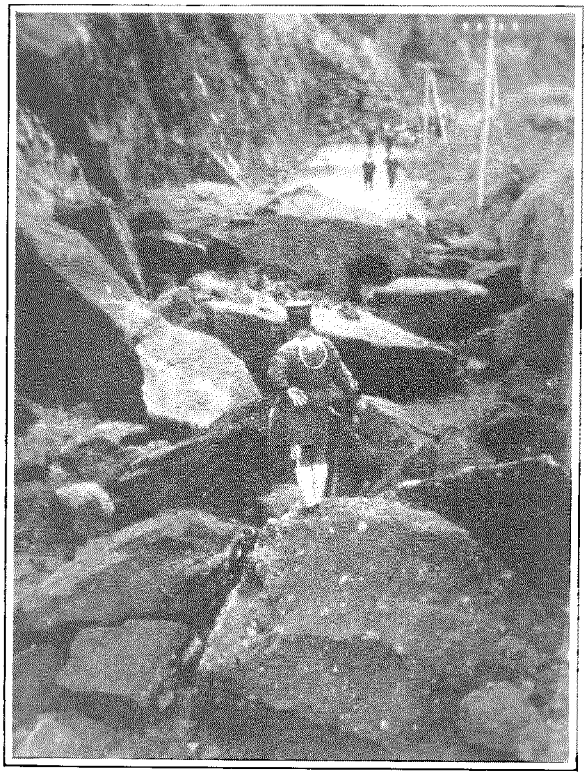

Figure 3—Fragments of Rocks Blocking All Traffic.

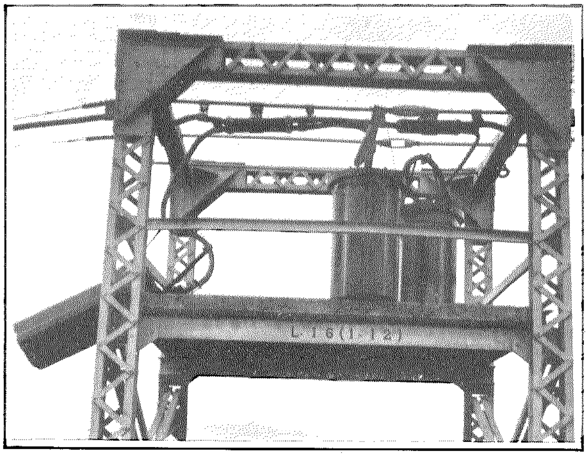

Figure 4—A Loading Coil Case Which Barely Escaped Dropping Down from the Tower.

The standards adopted in Japan for aerial cable line construction are as follows: standard span, 30 metres; length of wooden poles, 7.3 metres; tensile strength of messenger wire, 7,300 kgs.

It is of interest to describe the unusual damage sustained by the cable lines and the means taken to remove the troubles. On the cable line the following damage occurred:

Poles inclined	45
Guys cut off or pulled out	700 (approximately)
Loading coil cases moved on platforms	15
Loading coil cases fallen off platforms	5
Cables wound round messenger wires	20 places

In some places a stranded steel head guy, having a breaking strength of about 7,300 kg., was broken by shocks at a point 30 cm. under the ground. This caused the next auxiliary head guy to be broken off also, in consequence of

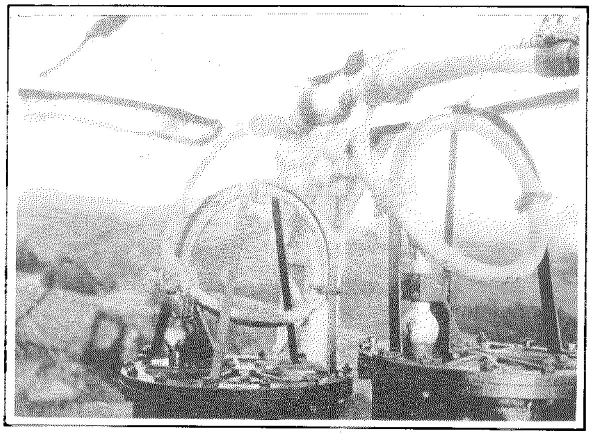

Figure 5—The Stub Cables Were Bent by the Violent Shocks.

which a number of successive poles, extending over 300 metres, were all inclined.

In the aerial part of the cable line, three loading coil cases are mounted on iron towers, which are designed to hold three more cases when another long distance telephone cable is installed. Each loading case contains 27, 30, or 35 loading coils, and weighs about 1,000 kg. Although these cases are so heavy that it was considered sufficient to place them on the tower platforms without fastening, they were jerked out of position by the extraordinary violence of the shocks, so that some of them fell off the platforms, while others hung precariously from the towers, as shown in Figure 4.

The shocks caused a certain amount of damage to the lead sheath cable stubs (Figure 5). Fortunately, the repair work was facilitated by making use of ring-formed slugs.

In the underground cable system, cast iron ducts having a length of 3 meters, an inner diameter of 76 mm., and a thickness of 9.7 mm. were laid at a depth of 1 m. along the road in the town of Hakone. These were so strained by the chasm formations that they were snapped at several points while the cables were crushed and the conductors torn asunder, as indicated in Figures 6, 7, and 8. Loading manhole No. 11 was slightly inclined, and its cover, together with the rim stone, moved 30 cm. out of place. Three loading coil cases set in the above manhole were overturned and two of them had to be replaced by new ones owing to breakage of stub cables with consequent lowering of insulation. The next manhole (a test-joint manhole), approximately 225 m. away in the direction of Odawara, was pushed up together with its foundation, breaking the ducts on both sides. The cables were also severely damaged and submerged in muddy water, with the result that all circuits in the cable were entirely blocked.

At points over 70 metres distance from the nearest test joint, ducts were also destroyed. Such points occurred most frequently where small streams were spanned. In addition, one of the calking joints slipped out, injuring the cables severely and putting them out of service.

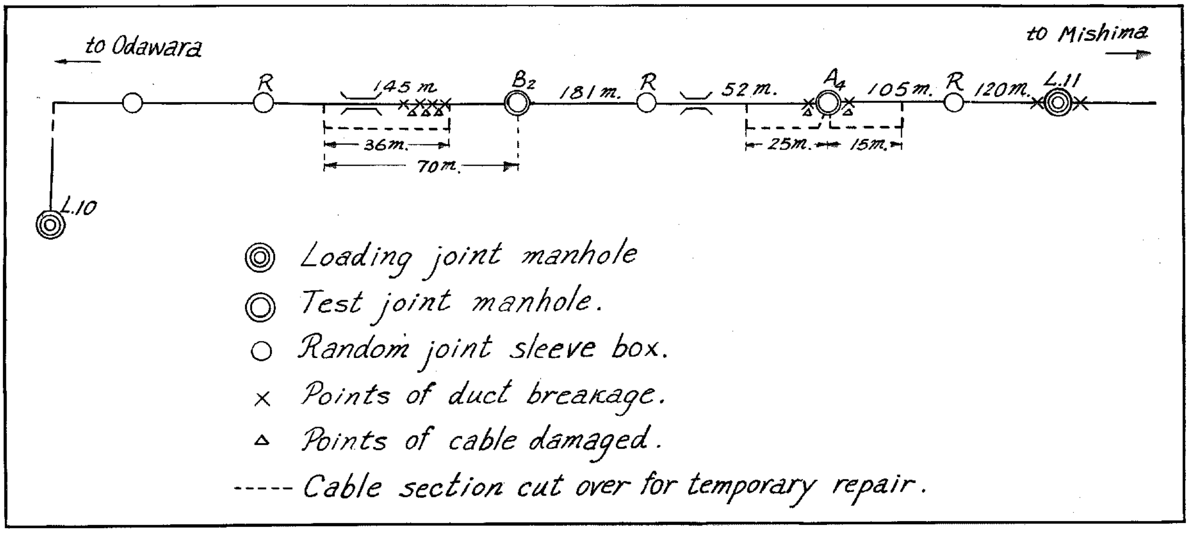
to Odawara
to Mishima
R
145 m
B2
181 m.
R
52 m.
A4
105 m.
R
120 m.
L.11
36 m.
70 m.
25 m.
15 m.
L.10
◎ Loading joint manhole
◎ Test joint manhole.
○ Random joint sleeve box.
× Points of duct breakage.
△ Points of cable damaged.
----- Cable section cut over for temporary repair.

Figure 6—The Section in Which the Underground Telephone Cable Sustained Heavy Damages.

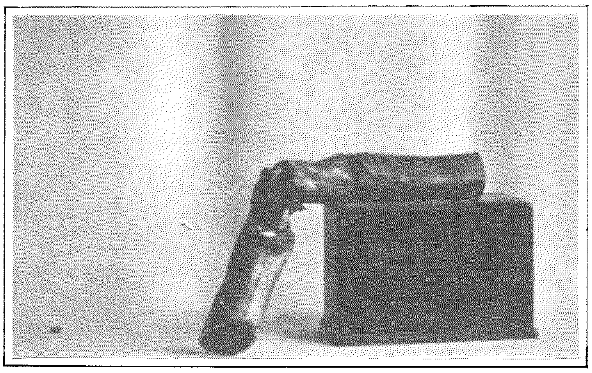

Figure 7—The Cable Crushed by Land Slips.

In view of all these damages there were no means of repairing the section between loading manholes No. 10 and No. 11 and consequently it was necessary to replace the whole section. In consideration of the tremendous difficulties encountered in pulling heavy cable drums up the steep hillsides, a number of these drums had been left for emergencies, and these were promptly made use of in the temporary restoration of communications.

These cables were laid directly on the road along the damaged section and jointed straight to the cable heretofore in use, omitting the loading coils in manhole No. 11. As the armoured cable was injured less than the unarmoured cable, it is expected that the sections between loading manholes Nos. 9, 10, and 11 will be cut over into a new armoured cable before long.

The town of Hakone is situated upon the shore of Lake Ashi, an old crater. At the time of the earthquake a terrific landslide engulfed a part of the town, and all the houses, numbering about a hundred, collapsed with the exception of a mere handful which were also on the verge of collapse. The underground cables in this district suffered the most serious damage.

As the road was blocked with enormous fragments of rocks and a long succession of minor shocks occurred after the big one, the work of conveying the heavy materials for repairing the cable was both extremely difficult and dangerous. The efforts of the foremen who carried out these difficult tasks, labouring at their complicated job till the evening of the day following the main disaster, is beyond description.

In view of the injury to the duct cables by violent shocks, notwithstanding the fact that they were installed in accordance with specially rigid requirements, we have learned among other things that armoured cable is better fitted for toll telephone construction in volcanic districts. Furthermore, loading coil cases on towers and in manholes should be fastened by proper means to prevent their moving or falling. Head guys and terminal poles should be stronger than those now in use.

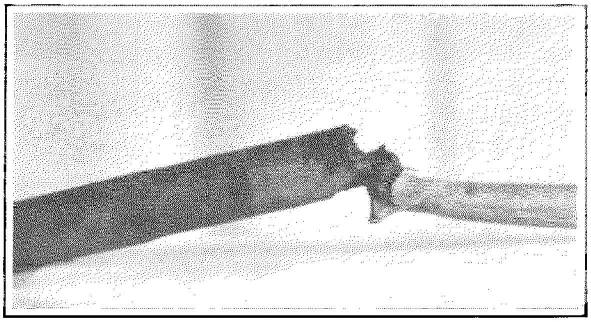

Figure 8—The Cable Broken by Snapping of Ducts.

A System for Simultaneous Telephony and Telegraphy Over Long Distance Small-Gauge Cables

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DURING the last few years the transmission of telephone and telegraph messages over long distances by means of underground paper-core cables has undergone considerable extension in the densely populated regions of Europe. These cables used to contain a certain number of special non-loaded pairs reserved for telegraphy. The placing of the telegraph and telephone conductors within the same cable led to a considerable economy in cables and duct space. This method, however, calls for certain precautions in order to avoid the disturbing effect of the telegraph currents on the neighbouring telephone circuits, and it might therefore be considered, both from the economical and technical standpoints, as the first stage towards simultaneous telephony and telegraphy. In view of the fact that a metallic circuit possesses certain transmission advantages over a ground return circuit, a second method was frequently applied. This consisted of using for the telegraphic transmission a metallic super-phantom circuit formed out of the available telephone channels, a practice which does away with separate telegraph conductors and leads to an important saving of copper.

The latter tendency of economising conductors has led to the development of two telegraph systems which, so far, have not found a wide application in most of the European countries. Early types of these two telegraph systems have been described in the April, 1925, issue of *Electrical Communication.* One of these systems involves the use of voice frequency currents, and makes practicable the simultaneous transmission of ten to twelve messages in each direction by means of two loaded pairs. The relatively high cost of the terminal installations permits the use of this system only over very great distances.

A second system, which may economically be applied either to short or medium long distances, is based on the well-known composite principles, the application of which on aerial lines dates back to the early days of the telegraph. However, its adaptation to work in conjunction with modern toll cables has necessitated important modifications and refinements in order to reduce the telegraph currents to values of the same order as the telephone currents and thus decrease interference.

The Bell Telephone Manufacturing Company, Antwerp, recently has undertaken the manufacture of this system which incorporates the latest improvements gained from several years of practical experience in the United States of America, where the system is in operation on a large scale. The equipment, which is known as the Metallic Polar Duplex Telegraph System, is briefly described below.

Advantages of the Composite Method

Figure 1 indicates a composited quad from which can be derived three telephone and two duplex telegraph circuits by using the Metallic Polar Duplex Telegraph System. Comparing the composite operation with the existing metallic super-phantom practice, it will readily be seen that for a given number of cable quads composite operation provides four times more telegraph circuits than metallic super-phantom, and also does away with the difficulties often experienced when it is required to set up and maintain long telegraph super-phantom circuits, due to the great number of conductors per circuit.

The use of separate non-loaded pairs for telegraph purposes does not prove economical except for very short distances. For longer circuits the composite system appears to be more rational and, in the case of existing cables containing telegraph non-loaded pairs, it may often be advantageous, in the event of an increase in the telephone traffic, to delay the installation of a new cable by loading the available telegraph pairs for telephone use, and by superposing on the latter, telegraph channels by means of the composite method.

Principles Underlying Composite Operation

The band of frequencies necessary for good telephonic transmission is situated between 300 and 2500 cycles. The maximum frequency that a given coil-loaded circuit may transmit efficiently will depend upon its cut-off frequency, which is normally slightly higher than the maximum useful telephone frequency. However, currents of frequencies lower than 300 cycles will be transmitted freely through such a circuit, and it is this lower band that is used in the composite telegraph system. The use of the lower band of frequencies for telegraph transmission precludes the use of 20-cycle ringing. It therefore becomes necessary to employ for signalling purposes a frequency higher than the band employed for telegraphy. 135, 500, and 1000 cycle systems have been used for this purpose.

Composite Sets

The telephone and the telegraph bands are separated by means of low-pass and high-pass filters respectively, connected in parallel at the extremity of the cable, and forming a unit generally known as a Composite Set (See Figure 1).

The low-pass filter of the telegraph branch passes frequencies lying within a band of from 0 to 80 cycles, this band width being such as to permit satisfactory transmission of the third harmonic when the speed of the telegraph transmission does not exceed 50 bauds. This speed corresponds to that of start-stop Teleprinters and Triplex Baudot working at a speed of 200 r.p.m. A further function of this low-pass filter in the telegraph branch is to present at the same time a high impedance and a high attenuation path to telephone frequencies, thus reducing to a minimum the loss introduced in the telephone circuit, and attenuating sufficiently the higher harmonics of the telegraph circuit which would otherwise give rise to an excessive "thump."

The telephone channel of the composite set forms, with the line repeating coil, a high-pass filter, designed to transmit all frequencies above 200 cycles. The high-pass filter also serves to

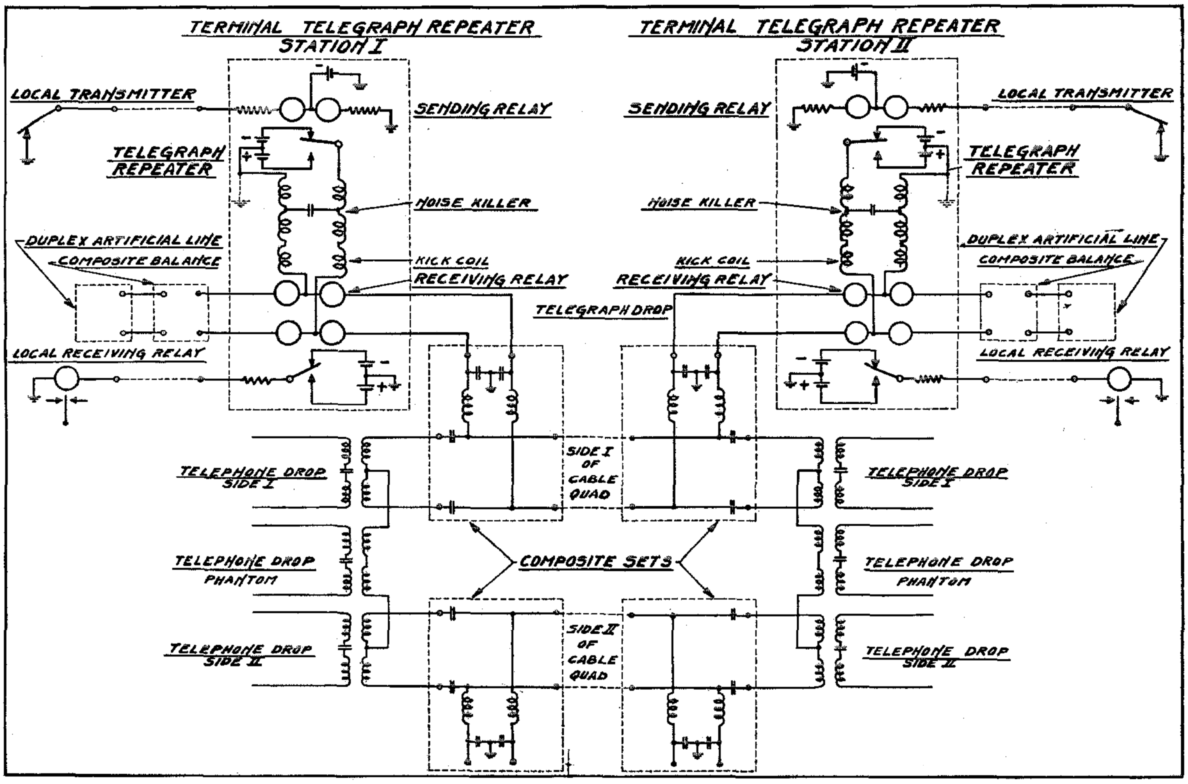


Figure 1—Composited Quad—Metallic Polar Duplex Telegraph System.

attenuate the telegraph frequencies sufficiently to avoid excessive "thump" in the telephone circuit.

A condenser connected to the mid-point of the repeating coil winding tends to minimize the effect of interference caused by the 20-cycle ringing current used for signalling in the local terminal equipment of the telephone circuit, and in addition gives protection against telephone receiver switchhook clicks, which give rise to transients harmful to telegraph transmission.

Advantage of a Metallic Return System

The modern underground telephone cable makes use of small gauge conductors which are generally loaded and employ intermediate telephone repeaters. Under these conditions it will readily be understood that the disturbing effect produced by the telegraph superposed on the normal telephone transmission would be excessive if the telegraph currents were not reduced considerably below those allowed in telegraph ground-return circuits, superposed on non-loaded open wire lines. On the other hand, the use of small current intensities and voltages on ground return circuits requires special precautions to reduce the detrimental influence of ground potential differences, and of the inductive interference of other telegraph circuits and power lines.

Figure 1 shows schematically the fundamental details of the circuit of the Duplex Telegraph Terminal Equipment associated with one side circuit of a quad. It may clearly be seen—without going into the well-known details of the differential Duplex Operation—that, due to the metallic return, the disturbing currents, described above, are practically eliminated and have no effect on the balance of the receiving relay, since they flow simultaneously in the same geographical direction in the two wires of the pair, and are equal in magnitude due to the close balance maintained between each pair in a telephone cable.

For actual operation involving the working of a number of circuits in a given office from the same set of batteries, it is desirable, although not absolutely necessary, to make a connection to ground at each station, as shown by the dotted line ground connections on Figure 1. These ground connections stabilise the system by providing it with a definite potential to ground and, moreover, facilitate the clearance of accidental grounds. Although this ground results in unbalancing the currents in the circuits the advantages of the metallic return telegraph still remain, since we may assume that the upper wire is employed for the transmission of signals and the lower one for carrying neutralizing currents only, whose effect will be to offset the influence of the disturbing currents in the other wire.

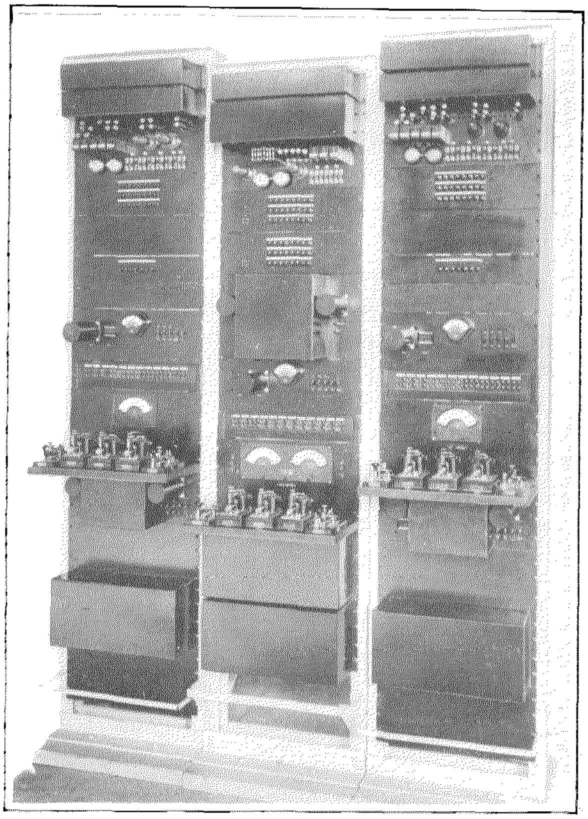


Figure 2—Demonstration Equipment of Two Terminal and One Intermediate Bays.

Single Commutation

One of the principal advantages incorporated in the system manufactured by the Bell Telephone Manufacturing Company is the improved relay design, which enables the equipment to be operated satisfactorily on a single commutation basis, thus effecting considerable economies. It will be noted from Figure 1 that only a single sending relay is used which successively applies to the line two batteries of opposed polarity. The double commutation method, which requires two relays whose armatures reverse the polarity of one battery, was largely employed in the earlier days in the United States. Double commutation was then preferred, as it was not possible in those days to obtain sufficiently close balance between the four windings of the relay. Due to improvements in manufacturing methods, the main difficulty of exactly balancing these windings as regards their resistance and number of turns has now been overcome, and as a result single commutation working is an assured fact. It is well known that the latter system necessitates more stringent conditions due to the fact that when the normal battery ground is provided, the signals passing over the line energise only one winding of the relay, whereas the others passing through the artificial line energise two windings. The artificial line is adjusted to have an impedance twice as great as that of the single transmitting wire; thus one line winding has to balance the two artificial line windings.

Single commutation requires double the battery voltage, but the same total ampere-hour capacity as that required for double commutation. On the other hand, it reduces the number of relay contacts by half, thus realizing a substantial reduction in cost and promoting ease of maintenance.

"Noise Killer" and "Kick Coil"

Reverting now to the question of telegraph interference in the telephone circuit, it can be said that the receiving-end "thump" is attenuated by the composite set to a point where it will not cause undesirable interference; greater protection than is provided by the composite set alone is necessary, however, to reduce the effect of sending-end "thump." In order that the additional equipment for this purpose may have the minimum effect on telegraph transmission, an arrangement is inserted in the transmitter branch of the telegraph repeater, where it affects outgoing signals only; this device consists of what is known as a "noise-killer" and a "kick-coil."

The "noise-killer," consisting of condensers and inductance coils (see Figure 1), is used to round off the square top of the telegraph signal, which would otherwise give rise to harmonics detrimental to good telephonic transmission. It constitutes a filter cutting off at about 80 cycles.

The "kick-coil" is required in connection with single commutation working in order to avoid excessive "thump" effect in the phantom circuit. It has its winding connected in parallel-aiding as regards the phantom circuit, and is therefore series opposing or non-inductive for the telegraph currents. The omission of the "kick-coil" would have the result of impressing a voltage in the phantom circuit due to unbalance created by single commutation working. The same effect occurs with a circuit operated on a double commutation basis when the two tongues of the transmitting relays fail to operate in exact synchronism.

Telegraph Relays

The receiving and transmitting relays used in this system are respectively the 209-FA and 215-A types. In order to furnish a good and reliable telegraph service, it is essential that very few relay failures occur during service periods; otherwise, valuable circuit time is lost and the relay maintenance expenses become an excessive factor in the cost of the exploitation of the system. This requirement has been realised in the above telegraph relays which have been designed to render satisfactory service for unusually long periods without any special attention.

The 209-FA is a very sensitive polarised relay which has been specially designed with a view to obtaining a high speed of operation with comparatively feeble current intensities over small-gauge cable circuits. It is provided with four accurately balanced line windings and two auxiliary windings, the latter forming part of the vibrating circuit. The function of the vibrating circuit is to reduce the distortion of telegraph signals and to increase the sensitivity of the relay. It is based on a modification of the well-known Gulstad principle, and although it forms one of the unique features of the system, it cannot be described here in detail, due to lack of space.

The 215-A relay possesses constructional features similar to the 209-FA type but is less sensitive and contains only two balanced line windings and no vibrating circuit windings.

All the contacts of these relays are protected by means of suitable spark-quenchers, which prevent pitting and corrosion of the contacts and eliminate harmful noises in telephone circuits.

An interesting feature of these relays is an arrangement which permits a ready removal of a relay from the circuit and its replacement when the relay in circuit requires adjustment.

A telegraph relay test circuit is provided by means of which the relays may be quickly and accurately checked or adjusted. Adjustment can be made without disturbing the use of a telegraph repeater, simply by removing the relay from the repeater, and plugging it into the test panel. The repeater is maintained in service by replacing the defective relay by a spare relay which has previously been adjusted in the test panel.

Terminal Telegraph Repeater

The telegraph apparatus shown schematically in Figure 1 constitutes a Terminal Telegraph Repeater for use between a metallic-return cable section and one or two ground-return loops. Two loops are required when the circuit is working duplex, one loop being used for transmission and the other for reception. It will be noted from Figure 1 that the local receiving loop operates on a double current basis, whilst the sending loop works on a single current basis.

Only one local loop is necessary when simultaneous transmission in both directions is not required. This method of working can be used with the same equipment by making a slight modification to the circuit of Figure 1.

Through Telegraph Repeater and By-Pass Set

For lines which are too long for direct transmission of telegraph signals from one terminal repeater to the other, Through Telegraph Repeaters are used. In practice the location of these repeaters is determined by that of the telephone repeaters. They are usually installed in every second telephone repeater station, the intermediate telephone repeater stations being provided with an intermediate composite set and a by-pass set, which provides a path for the telegraph currents to pass round the telephone repeater.

The intermediate telegraph repeater employs two 209-FA relays and two transmitting branches. Each relay is operated by the line current arriving from one direction, and repeats the signal in the line of the other side, differentially through the winding of the other relay.

The intermediate composite set is made up of two slightly modified terminal composite sets placed in the line on either side of the telephone repeater. The two telegraph branches of the composite set are connected together through the by-pass set.

The by-pass set consists of a retardation coil of high inductance and low mutual inductance between the windings, the object of this coil being to prevent currents feeding back from the output of the telephone repeater to the input through the telegraph branches of the composite set.

Monitoring Set

For both types of telegraph repeaters there has been designed a monitoring circuit which provides convenient means for obtaining a correct duplex balance, monitoring on the circuit, and locating troubles; signals passing through the repeater may be observed, and the attendant may communicate with other stations in both directions. The monitoring set includes differential milliammeters (one for the terminal set, two for the through set), polarised sounders, a telegraph key and a number of switching keys. A monitoring set is provided for several repeaters, and may be connected to any of the repeaters by means of patching cords.

Equipment Features

The apparatus is assembled on panel units mounted on bays 54 cm. wide and 3 m. high, similar in appearance to that of telephone repeater bays.

A complete terminal telegraph equipment unit consists of:

(1) a terminal repeater panel proper, with the two telegraph relays and the transmitting branch.

(2) One half of a composite balance panel for balancing the composite set in the telegraph circuit. (A complete panel containing two balance sets ensures the balancing of two terminal repeaters.)

(3) A Duplex Artificial Line intended to balance the cable circuit, and comprising series and shunt capacities and resistances which are inserted in the circuit by means of push button switches.

The following panels are required for a through repeater circuit:

(a) A Through Telegraph Repeater Panel including two 209-FA relays and two transmitting branches.

(b) A Composite Balance Panel.

(c) Two Duplex Artificial Lines.

An additional Duplex balance panel is required if a by-pass set is installed at the next telephone repeater station.

A terminal repeater bay serves either six complete telegraph repeaters without a monitoring panel or five repeaters with one monitoring panel. For a through repeater bay, the corresponding capacity is four panels for the former and three panels for the latter case. Usually, a monitoring panel is placed on every second bay.

Four-Wire Operation

Although this system has been designed for working on Duplex principles, it is equally adaptable for Simplex working. This method does away with the telegraph balances, but requires four wires to permit telegraph transmission in both directions. The repeater panels are so wired that by means of strapping, they can easily be made suitable for this method of operation. The Simplex method of working may in certain circumstances prove more economical, but it must always be borne in mind that it requires twice as many pairs as the Duplex method described above. Where abnormally long telegraph repeater sections are required it becomes necessary to use the four-wire method of operation, since it is possible to operate circuits of practically unlimited length in this way. Duplex operation cannot be considered reliable for distances exceeding 1000 km.

Non-Composite Working

This system may also be applied satisfactorily to non-composited pairs, either non-loaded or loaded, to which the principal advantages of the system, such as the weak line current, the metallic return and the highly sensitive and stable relays, still apply.

When the system is operated on the non-composited basis the location of telegraph repeaters no longer depends on that of the telephone repeaters. The maximum distance between two successive repeaters may then attain 220 km. for 0.9 mm. leads, and 300 km. for the 1.3 mm. circuits.

Figure 2 illustrates an equipment which was used for demonstration purposes, of two terminal and one intermediate bays. Each bay comprises, in addition to a complete telegraph repeater unit, a monitoring panel, a relay test panel and the necessary composite sets.

Noise

From experiments recently made on 1.3 mm. H-177-63 quad 520 km. long, it was found that the telegraph interference was inherently less than the telephone crosstalk on either of the three telephone circuits when full duplex teleprinter was being maintained on one of the side circuits.

Conclusion

Although the fundamental principles of compositing telephone cables are old, it is only quite recently that the art of compositing small-gauge cable circuits has been brought within the bounds of practicability, without impairing existing high grade telephone service.

In view of the reliability of cable circuits and ease of maintenance of the metallic polar duplex telegraph system, it is possible to envisage an extensive network of composited circuits being built up to meet the requirements of Administrations, bankers, and large industrial concerns with offices and plant located in widely separated parts of the country.

Developments in Start-Stop Telegraphy

The New Creed Printer

DEVELOPMENT of the applications of start-stop printing telegraphy naturally calls for progressive advances in the design of operating equipment in order to meet the more stringent demands which are made upon it. Such modifications in the design of teleprinter apparatus must take into account also economy of production, simplicity of operation, and ease of maintenance.

One of the principal reasons for modification in design is necessitated by the application of teleprinters to telegraph exchange service. In this important new role the teleprinter must fulfill all the conditions which are at present met by the telephone, but with the added advantage of giving transmission by telegraphy.

The new Creed teleprinter is designed to give all these facilities, and its construction, which is arranged on a unit basis, is of great advantage in the field for any unit of the machine in the event of trouble can be readily replaced, and the defective part examined and adjusted at some more convenient time. The removal of a particular unit does not in any way affect the adjustment of other units adjacent to it.

In general the principle of operation remains the same as in earlier types, but in the machine that has been developed for teleprinter exchange service a special device has been incorporated for transmitting back to the calling subscriber the exchange and number of the called subscriber, thus verifying the correctness of the connection. This facility is particularly useful in cases where it is desired to leave messages in the absence of the called subscriber.

The design of the machine has been laid out all in one plane, and all the units come within the limits of the travel of the paper carriage. When all the units are in place and screwed to the base plate all connections are made automatically by means of spring clips, the base plate and wiring forming one of the complete units.

The combined transmitting and receiving teleprinter is shown as a complete unit in Figure 1 and the assembly with the cover removed, in Figure 2. Figure 3 is a rear view of the paper carriage and travelling chariot; Figure 4 illustrates the detailed assembly of all the units of the machine. These units comprise the "answer back" device, cam unit, combination head, ink ribbon unit, keyboard unit, keyboard main base, main shaft, mechanical relay, motor starter unit, operating magnet, paper carriage, printer main base, transmitter unit, typehead, and wiring unit.

In cases where the machine is required for reception only, as in news distribution and ticker services, it is only necessary to undo two screws and remove the keyboard, which is a separate unit connected to the main base.

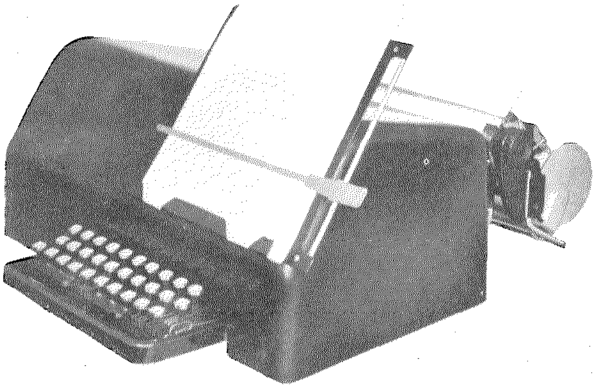


Figure 1—The New Creed Teleprinter—Complete Combined Transmitting and Receiving Unit.

There is only one high speed shaft in the machine. At one end of this shaft is the motor and, at the other end, the automatic motor starter. At right angles to this shaft and driven from it, are the printing head, the receiving cam shaft, the transmitting cam shaft and the "answer back" shaft.

In order to preserve accurate alignment of the printing, the typehead is provided with an outer bearing, and the typehead stop is fitted with an efficient shock absorber. All the shafts on this instrument are mounted in ball bearings, thus making possible the use of a smaller motor. The extensive use of ball bearings has also eliminated the need for frequent lubrication. A detailed view of the keyboard transmitter and receiving units is shown in Figures 5 and 6.

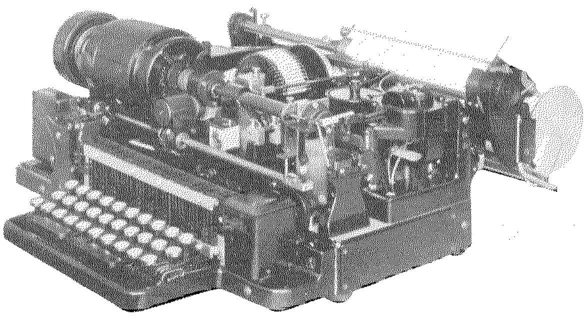


Figure 2—The New Creed Teleprinter With Cover Removed.

General Details of Units

The power of the motor used has been reduced to 40 watts, but it shows an efficiency of 60% at least. Double brushes are provided and, in addition, there is a special fan which ensures that even when the printer is totally enclosed within a specially designed silencing cover, the temperature is always maintained within safe limits.

Both ends of the motor casting are so constructed that they fit tightly in holes in a pair of plates by which they are supported. Electrical connections between the motor and its associated wiring, which is situated under the base of the machine, are made by means of four pins which come into contact with four springs through a hole in the base. These springs are attached to a block on the under-side of which is moulded a series-parallel switching arrangement, so that the connections may be adapted almost at once for using either A. C. series or D. C. shunt motors.

The governor, which is of the centrifugal type, and is totally enclosed in a bakelite case, is mounted on the free end of the motor spindle, and connection is made by means of a pair of brushes which rub on the slip rings.

A useful improvement over previous models lies in the incorporation of typewriter ribbon inking in place of ink rollers, the ribbon being so arranged that it automatically reverses when either reel is unwound.

The paper printing attachment unit comprises the platen carriage which moves from right to left as printing along each line proceeds. The main casting carries the feed and control mechanism, and the paper chariot which carries the paper roll.

The platen carriage is mounted on the main casting by means of a running bar along which slides the grooved portion of the frame, and a keyed spindle which passes through the centre of the platen.

Attached to the carriage is a rack which engages for letter feed purposes with a toothed wheel situated in the main casting. The line feed is accomplished by rotating the keyed shaft which passes through the platen, friction between the keyed spindle and the platen being reduced to a minimum by four rollers which serve as a pair of keyways. The principal components of the carriage are a light casting, a pair of end plates which provide bearings for the platen and a pair of rollers which are fitted on a pivoted axis, and are held in contact with the platen by means of a pair of flat springs.

Each of the rollers extends practically half the length of the platen in order to give an equal application of pressure throughout the width of the paper. Both the platen and the pressure rollers are rubber-covered.

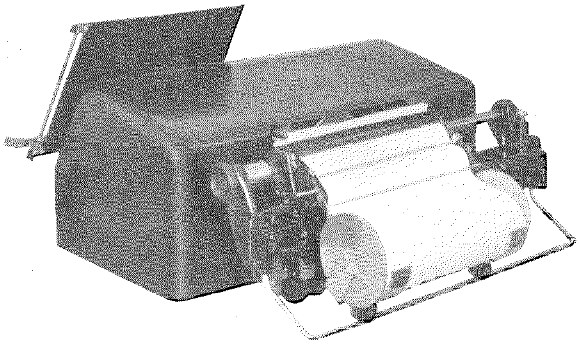


Figure 3—Paper Carriage and Travelling Chariot—Rear View.

The mechanism controlling the carriage movements is mounted on the main casting. It consists of the letter feed mechanism, the carriage return mechanism, and the line feed mechanism.

In order to warn the operator of the approaching end of each line the mechanism is so arranged that a line feed bell rings automatically at a point ten characters before the end of the line. The bell device is fitted to the page printer attachment.

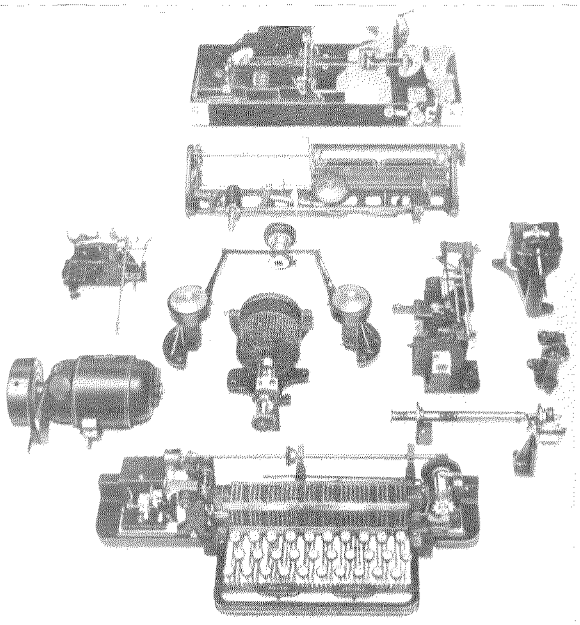


Figure 4—Detailed Assembly of All Units of New Creed Teleprinter.

The teleprinter can be mounted on any table conveniently placed for electricity supply, and requires no special fitting of any kind. The plug socket through which the electrical connections are made may be fastened either to the table or to an adjacent wall.

A special silencing cover, in place of the dust cover normally used, can be fitted on the machine in cases where quiet operation is of considerable importance.

The overall dimensions of the machine with its dust cover in position are: width, 19½ in.; depth, 23½ in.; height 10½ in.

Operating Features

The teleprinter is capable of operation by any typist, at speeds up to 66 words per minute, and it prints on a message roll 8½ in. wide. It utilises a 5-unit code in which the current permutations forming each character are all of equal length. Every signal transmitted is preceded by an impulse which starts the receiving printer, and is followed by an impulse which brings the printer to rest again. In this way it will be seen that the difference in speed between two or more machines is not cumulative, as for each letter transmitted the machines start together. The signalling code used by this machine is shown in Figure 7.

Where more than one copy is required, either carbon backed paper in a continuous roll, or manifold books of separate sheets interleaved with carbon paper, may be used. With the former three good copies can be obtained, and with the latter up to ten copies.

For single current operation, the line current necessary is from 17 to 20 milliamperes, but for double current only 12 to 15 milliamperes is required.

A single transmitting armature is used which ensures that all signals have the same characteristics. The contact pressure is about 50 grammes, and oscillograph records show that there is a complete absence of armature rebound.

On the receiving side a high grade polarized electro-magnet is used so that the new teleprinter can be operated over long distances without the use of an additional line relay. This electromagnet has two windings connected in series, each having a resistance of approximately 100 ohms.

The teleprinter has been so designed that tape and page printing attachments are interchangeable. Only a momentary interval is required to

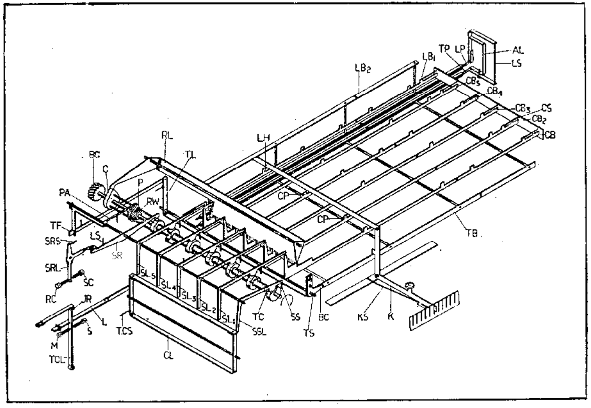


Figure 5—Keyboard Transmitter Unit.

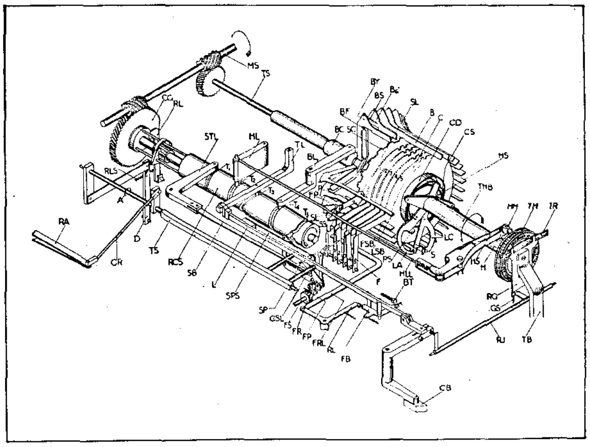


Figure 6—Receiving Unit.

replace one attachment by the other, as a greatly improved form of mounting has been adopted.

Either of the above units can be removed by first operating a latch at one end of the support casting, and then lifting the other end from a vertical stud by which it is supported.

Where telegraph apparatus is operated on a double current simplex basis (transmission in one direction at a time) a send-receive switch is provided for changing over from the sending to the receiving condition, and vice versa. It is impossible for the operator to omit to change back to the receiving condition after the conclusion of transmission, as the switch is incorporated in the transmitter unit, and is entirely automatic in operation.

As the teleprinter may be left unattended for considerable intervals of time, some means must be provided for stopping the machine after transmission has ceased. To effect this it is fitted with an automatic starting switch which closes the motor circuit immediately the printer electromagnet is operated. If no signal is received for a period of two minutes the switch automatically breaks the motor circuit again. The motor is thus kept at rest except during the periods in which signals are actually being received.

To meet the requirements of teleprinter exchange services, the instrument is equipped with the previously referred to "answer back" mechanism which has not hitherto been provided in any other printing telegraph apparatus. On depressing a key on the teleprinter keyboard marked "Who are you?" a special signal combination is transmitted over the line, causing the "answer back" device on the "called" subscriber's machine to repeat back its exchange and number to the "calling" subscriber.

Principles of Operation

Every character is allotted a combination of five units as shown on the code chart in Figure 7, the black circle representing current intervals and the white circles no current intervals. This combination for each individual letter is passed between the transmitter and the printer.

When a key is depressed it engages a clutch, to which is coupled a series of cams which control the sequence of the transmitting operations. Under the control of these cams the depressed key is locked, and all other keys on the keyboard are prevented from moving until the selected character has been transmitted.

The depression of each key is designed to arrange in a particular manner five bars which are capable of being moved longitudinally, a displaced bar corresponding to a "marking" signal, and a stationary bar to a "spacing signal." Under the control of the cams, each of these bars determines in correct sequence the characteristic

START-STOP CODE

A	WHO ARE YOU	○●●○○○●	P	0	○○●●○●●
B	?	○●○○●●●	Q	1	○●●●○●●
C	(	○○●●●○●	R	4	○○●○●○●
D	:	○●○○●○●	S		○●○●○○●
E	3	○●○○○○●	T	5	○○○○○●●
F		○●○●●○●	U	7	○●●●○○●
G		○○●○●●●	V	)	○○●●●●●
H		○○○●○●●	W	2	○●●○○●●
I	8	○○●●○○●	X	£	○●○●●●●
J		○●●○●○●	Y	6	○●○●○●●
K		○●●●●○●	Z	.	○●○○○●●
L	/	○○●○○●●		CAR. RET.	○○○○●○●
M	'	○○○●●●●		FIGS.	○●●○●●●
N	-	○○○●●○●		LTRS.	○●●●●●●
O	9	○○○○●●●		COL.	○○●○○○●

SPACE ○○○●○○●

KEY:- ● = MARK
○ = SPACE

Figure 7—Signalling Code.

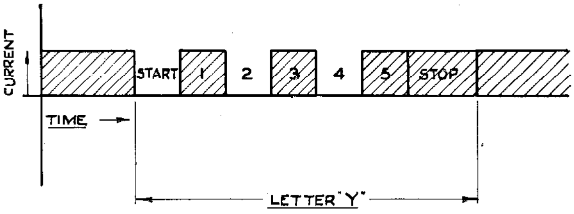
of one current unit of the combination transmitted.

In addition to the current impulses forming the particular character combination, two additional impulses are automatically transmitted every time a key is depressed. One of these impulses precedes the character combination and serves to engage a clutch through which the printing selector mechanism is driven; the other, which follows the character combination, causes this clutch to be disengaged after the signal has been translated. A graph of line current for the transmission of the letter "Y," plotted against time for both single and double current working is shown in Figure 8.

The line currents at the receiving end of the line pass through the windings of an electromagnet which turns a shaft into one of two positions for the duration of each signal impulse.

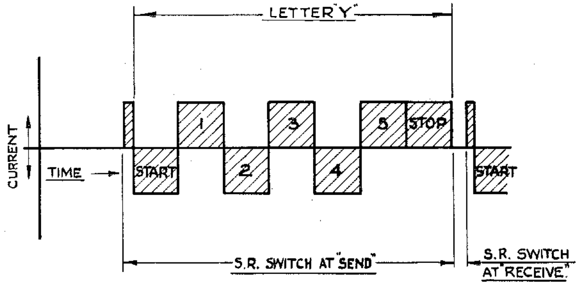
Five small levers are ultimately set backwards or forwards in the same combination as the moving members in the transmitter, this being effected by a synchronised striker which traverses the levers, and is struck forward in front of each lever in succession. The position of the shaft controlled by the electro-magnet determines whether or not the striker will displace the lever, and since the position of this shaft is dependent upon the incoming signal impulse, the character combination selected by the transmitter is accurately reproduced in the printer.

The last stage in the selection of the character to be printed is carried out by an application of the principle of the combination lock, by virtue of which one of a series of radial latches is caused to drop and entirely stop a rotating typehead in such a position that the required type is interposed between a small hammer and the paper. The hammer is operated during the early part of the selection cycle for the next character, and the impression is thus made on the paper.



SINGLE CURRENT CLOSED CIRCUIT

(a)



DOUBLE CURRENT

(b)

Figure 8—Graph of Line Current.

Transmission Testing of Subscribers' Apparatus

By L. C. POCOCK, M.Sc., A.M.I.E.E., A.C.G.I.

International Telephone and Telegraph Laboratories, Incorporated, Hendon

AN impartial enquirer into the state of development of the telephone art would find two facts which seem little in keeping with the high scientific standard reached by telephony, and with the wide field of science which has been drawn upon during the last twenty years to aid in the annihilation of distance for the spoken word. "Sound" has shown less amenability to physical and experimental study than other branches of physics; the study of electrical physics has indeed so far surpassed the more ancient science of sound that the older borrows from, and is explained by the newer, whence we have expressions such as "sound field" and "acoustic impedance." When to the difficulty of measuring sound in general is added the necessity of measuring that most complicated combination of sounds called speech, it is no longer surprising that the precision of electrical measurement attained in the balancing of circuits, the adjustment of repeaters, and the forecasting of attenuation, is not duplicated in the data that can be obtained upon the acousto-electric ear (transmitter) and the electro-acoustic mouth (receiver) of the telephone system.

Many laboratories have in the early days of their history dreamed of, and possibly worked for, a scientific and impersonal measurement of what is known as transmitter and receiver efficiency. This is not the place for a discussion of the difficulties and, for the most part, failures which have resulted. It is true that machines capable of measuring the efficiency of particular types of transmitters and receivers have been built, but their performance is empirical rather than scientific, their calibration is most often by voice and ear test, rather than in fundamental units, and their use is in most cases restricted to the laboratory. Doubtless, machines will come into wider use, a more perfect machine will be developed, and then, also, transmitters and receivers will be diligently tested and studied in quarters that at present ignore such means as are available for this work. To the impartial enquirer, the second surprising fact is that there are countries in which the telephone system includes skillfully designed and constructed transmission circuits but is lacking in standards of performance for the transmitter and receiver at the end of the line.

Much has been accomplished towards overcoming these deficiencies during the last ten years and the time has now come when the Comité Consultatif International, having established a Transmission Reference System in Paris, is able to approach the problem of recommending the minimum performance to be tolerated in the subscribers' apparatus for long distance calls. This recommendation has far reaching consequences: first, because, to interpret it, each Administration must acquire certain standardised and calibrated apparatus, and second, because when the efficiency of the subscribers' apparatus comes under consideration, and into a field of measurement, large economies result from more scientific planning than was formerly possible.

Looking a little more closely at this question of economy, it will be realised by all telephone engineers that the construction of a long distance communication channel, for example, involves an economic study in which the cost of copper, line construction, loading coils, and repeater stations enter; it will be shown that due consideration must be given to the efficiency of transmitters (and receivers); further, articulation or freedom from speech distortion is now recognised as an important factor to the extent that an improvement in articulation may be brought into the economic study as a negative attenuation, that is, as equivalent to an increase of loudness efficiency. The result of the study determines the most economical construction for a system capable of giving a certain grade of service, that is to say, for example, a grade of service not worse than that afforded, with ordinary transmitters and receivers, on zero loops with interposed attenuation equal to 3.5 népers

TABLE I

Weight of Single Conductor		Relative Efficiency Decibels	Cost of Copper in 10,000 loops		Value of decibel per 10,000 subscribers' loops	
			Copper per ton*		Copper per ton*	
lb./mile	Kg./Km.		£75	£41	£75	£41
20	5.6	0	£13,400	£7,400		
10	2.8	–2.0	6,700	3,770	£3,350	£1,815
6.5	1.8	–3.0	4,360	2,400	2,340	1,370

* Copper priced at £75 and £41 per ton or 18.2c. and 10c. per lb.

(30.4 decibels). In such a case the losses in the two terminal loops, including any loss due to the current supply to the transmitter being less than over a zero loop and any gain expressed in decibels and derived from use of improved quality instruments, must not exceed 1.5 népers (13 decibels) if the equivalent from one local exchange to the other is 2 népers (17.4 decibels). The loss due to reduced current supply may be quite half or more of the allowance for the local loops. Consequently, two propositions may be set up:

1. Any improvement in transmitter efficiency or articulation offered by a new design of transmitter will allow an increased attenuation in the trunk, or a reduction in the efficiency of the local loops without reducing the service below the predetermined grade. Any increase of permissible attenuation in either case has a direct financial capital value.
2. In order that any exchange area may be laid out with maximum economy within the limits of a predetermined grade of transmission, it is necessary to know how the transmitter efficiency varies with the current supply, and what the transmitter and receiver efficiencies and articulation values are in relation to the instruments and circuit used in defining the grade of transmission furnished.

Without precise knowledge regarding the efficiency and articulation of the transmitters and receivers employed, it would be necessary to guess at the gauge of wire to be used for the subscribers' loops, and this would result either in ensuring a margin to the grade of service required by supplying too much copper, or in the contrary case, the grade of service would fall below the intended value.

As an indication of the money values involved in alternative layouts, Table I has been prepared showing the cost of copper and approximate relative transmitting efficiency of loops one mile long, using different weights of copper conductor. This enables the value of one decibel gain or loss in transmission to be estimated.*

This simple example indicates that the cost of subscribers' lines for a given grade of performance will show appreciable reduction if the average transmitter efficiency is improved by comparatively small amounts. In actual practice, the lines are naturally of varying length and the concentration, or number of lines of a given length is some function of the length, so that the problem is more complex, involving often the joining up in series of two different types of conductor. It must be evident that this work cannot be carried out with satisfactory transmission results and without undue extravagance unless it is based upon some consistent plan, of which the essence is a foreknowledge of the transmission efficiency of the subscribers' apparatus under any given loop conditions.

The necessary data relating to the apparatus employed in any particular country can be obtained by comparison with particular pieces of telephone apparatus, which represent standards of comparison analogous to the physical standards of weight and length preserved in the National Laboratories. These standards of telephone performance, in the shape of groups of transmitters and receivers should be as invariable as possible. It is to some extent scepticism of the constancy of the carbon transmitter standard that has been responsible for the rather widespread neglect of systematic investigations by the voice and ear method into the performance of subscribers' apparatus.

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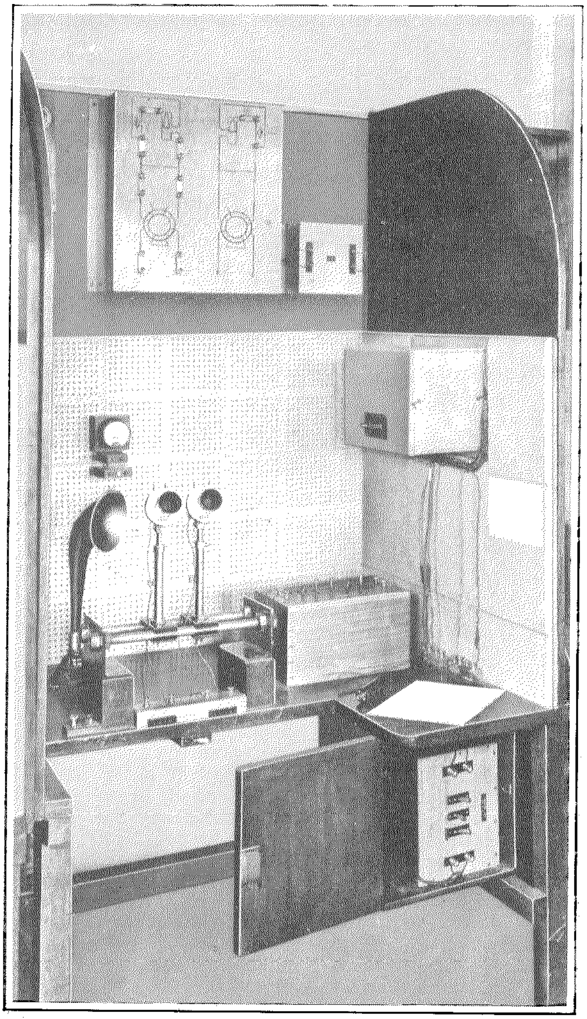
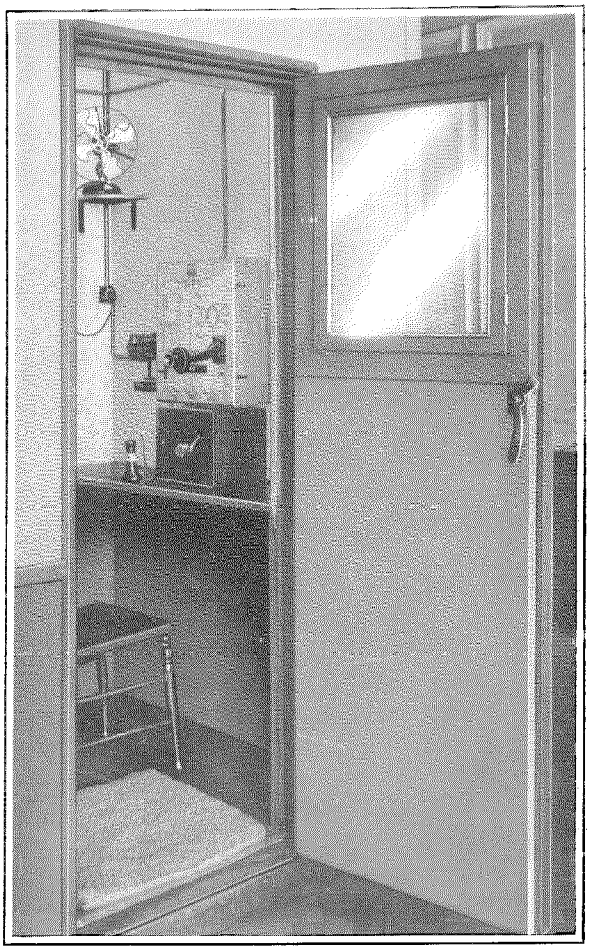
* Similarly, a gain in articulation has a money value according to the number of decibels gain that would produce an equal improvement in the grade of service. The equivalent values have been determined, but cannot be usefully discussed because, as in efficiency testing, the results depend upon the technique adopted. Until a standardised method of test is in vogue, it is undesirable to quote figures unless indeed accompanied by an exact account of the procedure adopted. Such an account may be found in *Speech and Hearing* by Harvey Fletcher, where (p. 272) it is shown that 1 decibel is approximately worth 2½% articulation. See also "A Theoretical Study of the Articulation and Intelligibility of a Telephone Circuit," by John Collard, *Electrical Communication*, January, 1929, pp. 168-186.

Time will show whether scepticism was justified. Evidence accumulates that *well made* transmitter standards do not vary as much as has been supposed, while on the other hand, their human observers vary from one to another in the characteristics of voice and ear, and, what is more important, do not establish sufficiently exactly the technique or method to be adopted in making a test. Put very briefly, a large number of observers and a large number of observations are required in order to obtain a result by voice and ear measurement that is significant in the sense that it represents the average performance of telephone apparatus in service.



Arrangement of Apparatus at the Talking End



Silence Cabinet.

As it is frequently inconvenient or impossible, to employ more than three or four observers, it is in such cases more than ever necessary to define the testing technique with a view to rendering the results of so few observers constant and representative, as well as reproducible by other groups of observers in other laboratories. The same arguments of eliminating unnecessary variables apply to the employment of one standard set-up of carefully defined testing apparatus in all laboratories.

For many years, the laboratories associated with the International Standard Electric Corporation have maintained in London a standard of the type described. Transmitter and receiver standards have been maintained for the associated manufacturing companies, and in some cases these standards have been supplied to telephone administrations. The standards have been based upon those maintained almost from the birth of telephony by the American Telephone and Telegraph Company, and equality with the parent standards has been maintained by a periodic interchange of standards between London and New York. A precisely defined testing circuit and a defined technique have been in use, and continual attention has been paid to securing methods of testing which represent average service conditions, and at the same time yield results which are reproducible in other similarly equipped laboratories.*

The development of voice-ear measurements has recently taken a step forward. A standard has been established which can be checked by physical measurements, thereby removing the chief objection to the old type of transmitter and receiver standards, namely, the difficulty of detecting whether a drift in the value of the master group of standards occurs over a long period of years. The standards used in telephone laboratories will continue to be, or to resemble, ordinary types of telephone apparatus, but their calibration will rest ultimately either directly or indirectly upon the Transmission Reference System, which can be set up anywhere to a specification, and verified in performance by physical measurements.

The establishment of the Master Transmission Reference System in Paris[1] benefits telephony as a whole. For the first time, there is a standard adopted by common consent, and for the first time two different telephone administrations have a chance of discussing the overall transmission between two telephones in their separate areas in terms of a common basis, and therefore, in mutually intelligible terms.

The Transmission Reference System establishes a standard, but in order to use the standard, equipment and laboratory personnel are needed, as well as the adoption of standardised technique. The Comitè Consultatif International has accordingly made recommendations regarding the essential requirements of the testing circuits (or working standards) to be used by telephone administrations.[2]

Apparatus in accordance with these requirements, and furnished with a number of auxiliary features found to be desirable for facilitating and expediting the testing, is installed in the International Telephone and Telegraph Laboratories, Incorporated, in London. The illustrations show the arrangement of apparatus at the talking end, and one of the silence cabinets in which listening observations are made.

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*The method of maintaining standards, the testing circuit and the technique are described in a privately circulated publication entitled *Laboratory Series*. Administrations interested in transmission testing are invited to apply for copies to the Information Department, International Telephone and Telegraph Corporation, Connaught House, Aldwych, London.

[1] "European Telephony as Affected by the International Telephone Committee—'C. C. I.' " *Electrical Communication*, July, 1927.

[2] A circuit recommended is substantially that used for the past few years by the International Standard Electric Corporation, and its associated Companies.

Alternative Trunking for Telephone Traffic in a Multi-Office Area

THE principle of code translation coupled with the use of tandem centres provides an economical method for handling small groups of outgoing trunks in large areas. For heavy groups, large capacity switches and grading are extensively employed. A new application of alternative trunking has been developed by Standard Telephones and Cables, Ltd., and is described in British Patent Spec. No. 346370, which provides a considerably more efficient method of trunking medium size groups which are too large to be tandemed and too small to take advantage of the large capacity switch.

Hitherto, alternative trunking has been understood to express an arrangement capable of cancelling an unsuccessful set-up, and of admitting connection through other switches. A more efficient method of taking advantage of this principle goes a step further by deliberately providing insufficient direct outgoing trunks, with the knowledge that the overflow traffic may be carried economically by an alternative route through a tandem centre.

The area conditions which will permit the greatest economies to be obtained comprise one or more switching centres with direct circuits to the remaining exchanges in the network. If the junction groups radiating from the switching centres are large, with high busy hour occupancies, the greatest efficiency will be obtained by this new application of Alternative Trunking, as may be seen from the figures given below.

It is a well-established fact that the efficiency of a group of trunks is dependent upon the accessibility between the trunk circuits and the searching switches, e.g., with full availability and the probability of loss of one in 1,000.

A group of 6 trunks carries 1.14 traffic units (34 equated busy hour calls).

A group of 10 trunks carries 3.1 traffic units (93 equated busy hour calls).

A group of 50 trunks carries 32.5 traffic units (975 equated busy hour calls).

This is equivalent to an average trunk occupancy of:

$$\text{6 trunks: } \frac{1.14}{6} = .19$$

$$\text{10 trunks: } \frac{3.1}{10} = .31$$

$$\text{50 trunks: } \frac{32.5}{50} = .64$$

If there is a slip between banks in the multiple, each outlet will carry a volume of traffic equal to the average occupancies shewn. If there is no slip the earlier choices will carry a very much greater volume than the later choices although the average remains unaltered.

TOTAL TRAFFIC OFFERED	1.14 T. C.	3.1 T. C.
1st Choice carries............	.531	.756
2nd " "	.354	.670
3rd " "	.163	.562
4th " "	.066	.437
5th " "	.020	.307
6th " "	.005	.189
7th " "	....	.104
8th " "	....	.047
9th " "	....	.019
10th " "	....	.006
Overflow......................	.001	.003

It is a significant fact that out of 1.14 T. C. the first four choices carry 1.113 T. C. or 97.7% of the whole load. Similarly out of 3.1 T. C. the first seven choices carry 3.025 T. C. or 97.6% of the whole.

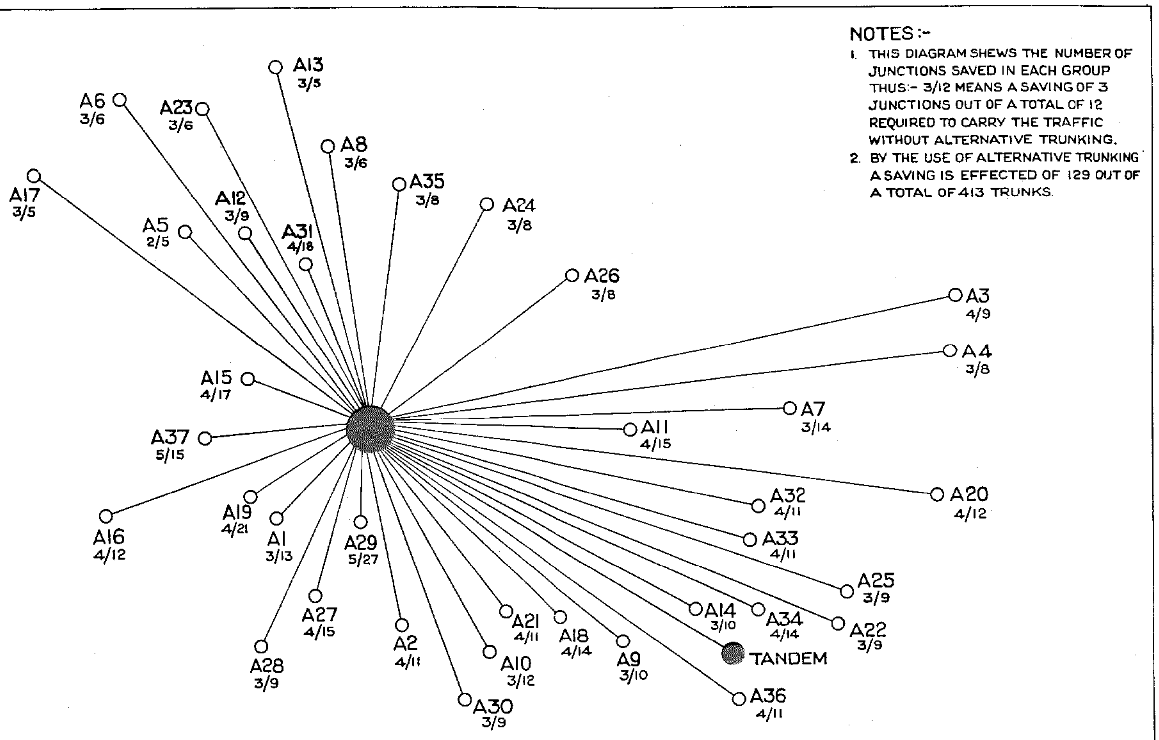
It follows that if the last choices are removed, a relatively small percentage of the traffic will need to be carried by an alternative route. In order to preserve the occupancies of the early choices it is necessary that the same volume of traffic should be offered to these outlets as before. If all the direct circuits are in use, the call is routed through a tandem exchange—the exchange code being suitably translated.

The number of additional circuits through the tandem centre required to carry this overflow will depend upon the average occupancy. It has already been shewn that the average occupancy for a group of 50 circuits is .64 T. C. and each additional circuit will carry at least this amount of traffic, which is considerably more than the traffic carried by the last five choices of the group of 10.

The number of late choice trunks, which it is wise to save, will depend upon the length, cost and existing plant. A slightly smaller percentage should be removed from the larger groups. Usually the heavier groups cover the shortest distance.

Alternative trunking can be applied with equal advantage to any of the various methods of multipling between groups of banks now in use. For example if the traffic in a particular route is 3.1 T. C. and the conditions are such that it is most economical to provide only 7 trunks, the overflow traffic to be routed through the tandem centre will be .075 T. C. If there is no slip the first seven outlets will carry the traffic shewn. If there is a complete slip between banks, each of the seven outlets will carry $\frac{3.1-.075}{7}$ T. C. Various forms of reversals and slips between shelves will also alter the occupancies of the 7 outlets but the overflow will remain unchanged.

The circuit arrangements to permit alternative trunking have been incorporated in the Translator Bypath System, and equipment for the London area is being manufactured by the Standard Telephones and Cables, Limited for the British Post Office. In one exchange, to which the arrangement has been applied, it was found that 129 out of 413 direct trunks with their terminal apparatus could be dispensed with for an insignificant increase in the number of tandem junctions. The sketch shows the number of junctions saved in each route, calculated on the basis of a loss of 1 in 500.



NOTES:-
1. THIS DIAGRAM SHEWS THE NUMBER OF JUNCTIONS SAVED IN EACH GROUP THUS:- 3/12 MEANS A SAVING OF 3 JUNCTIONS OUT OF A TOTAL OF 12 REQUIRED TO CARRY THE TRAFFIC WITHOUT ALTERNATIVE TRUNKING.
2. BY THE USE OF ALTERNATIVE TRUNKING A SAVING IS EFFECTED OF 129 OUT OF A TOTAL OF 413 TRUNKS.

DIAGRAM
(SHEWING SAVING IN JUNCTIONS DUE TO ALTERNATIVE TRUNKING)

Trunk Route	Number of Trunks required to carry traffic	Trunks Proposed	Traffic Overflowing
A.1	13	10	.10
A.2	11	7	.16
A.3	9	5	.15
A.4	8	5	.11
A.5	5	3	.04
A.6	6	3	.09
A.7	15	11	.13
A.8	6	3	.05
A.9	10	7	.09
A.10	12	9	.14
A.11	15	11	.14
A.12	9	6	.08
A.13	5	2	.07
A.14	10	7	.08
A.15	17	13	.19
A.16	12	8	.15
A.17	5	2	.06
A.18	14	10	.14
A.19	21	17	.19
A.20	12	8	.13
A.21	11	7	.14
A.22	9	6	.10
A.23	6	3	.05
A.24	8	5	.07
A.25	9	6	.11
A.26	8	5	.06
A.27	15	11	.14
A.28	9	6	.07
A.29	27	22	.06
A.30	9	6	.08
A.31	18	14	.17
A.32	11	7	.18
A.33	11	7	.15
A.34	14	10	.14
A.35	8	5	.06
A.36	11	7	.17
A.37	14	10	.21
	413	284	4.25

To the overflow traffic of 4.25 T. C. should be added the traffic to 110 other exchanges via a tandem centre, totalling 51.7 traffic units. This tandem traffic, while graded in groups of 26, requires 74 trunks. When the overflow traffic is added, the total of 55.95 traffic units could be calculated in graded groups of 40, since in the exchange under consideration the outlets formerly allocated to direct trunks could be used to increase accessibility. The number of trunks now required is 76—an increase of 2 only.

It should be appreciated that the various overflow traffics are of a peaky nature, and could not be added as normal traffic except for the fact that the overflows from the different groups are non-coincident.

Some addition to the trunks outgoing from the tandem centre to the various offices for handling the "Alternative Route" traffic will also be necessary. In no case is the overflow traffic sufficient to demand more than one additional circuit and in fact increase is necessary at all only when the groups of trunks are already fully loaded. The average traffic carried by the trunks outgoing from the tandem centre is slightly over .7 T. C. and on this basis the additional traffic of 4.25 T. C. which it is proposed to pass through the tandem centre will necessitate an additional 6 outgoing circuits.

The following table will enable the total trunk miles saved by the use of alternative trunking to be appreciated:

	Average Miles Length	Without Alternative Trunking		With Alternative Trunking	
		Qnty.	Total Miles	Qnty.	Total Miles
Direct Circuits.........	4	413	1,652	284	1,136
Outgoing to Tandem Circuits.............	5	24	320	76	380
Additional Outgoing from Tandem Circuits.............	5	.....	.....	6	30

The circuits to and from the tandem centre will be of heavier gauge than the direct circuits and a certain allowance is necessary for the greater cost of these additional circuits.

The principles of alternative trunking can also be used in the reverse sense to permit the direct trunking of a portion of a trunk route which would otherwise be tandemed entirely.

Other advantages from alternative trunking are obtained by the fact that seasonal increase in certain trunk routes can be absorbed by the common group. In a similar way the breakdown of any particular trunk route may be minimised by the automatic use of the alternative route. In very large areas in which there are frequent extensions, the principles of alternative trunking introduce a flexibility which makes it unnecessary to estimate future requirements so accurately, or to provide so much idle capacity of both inside and outside plant for future growth.

The Universal Mounting Plate

By L. H. WEBB, B.Sc.

International Telephone and Telegraph Laboratories, Incorporated

WITH the introduction of the common battery telephone switchboard, originally known as the No. 1 Relay Board, in the early part of the twentieth century, the provision of mounting plates for relays and other associated apparatus assumed considerable importance. Mounting plates required fell generally into two different classes, those mounting from ten to twenty, or even more, pieces of similar apparatus, and those mounting the same quantity of dissimilar apparatus. At first both types followed the same design with all apparatus mounted on cold rolled mild steel plates $\frac{7}{32}$ in. or $\frac{3}{8}$ in. thick. Similar apparatus was grouped together in single rows on strip plates, and mixed apparatus was assembled in rows, either on strip plates or on wider plates accommodating several rows.

The rapid extension of the telephone service and the increasing demand for apparatus necessitated the manufacture of as many components as possible by means of press tools and led to the development of lighter apparatus. When the punched frame relay, usually called the flat type relay, was introduced, a new type of plate was designed to mount twenty of these relays under a common dust cover. It is manufactured entirely by press tools, as may be seen from Figure 1, and provides a satisfactory type of mounting for similar pieces of apparatus since it can be produced economically and the quantities required are sufficient to justify the necessary expenditure on tools. The problem of an improved mounting for dissimilar pieces of apparatus remained unsolved until the International Telephone and Telegraph Laboratories evolved the Universal Mounting Plate. Before describing the Universal Mounting Plate, however, it will be well to review in detail some of the difficulties surrounding the production of the existing type of mounting plate for dissimilar apparatus.

These plates are used to mount a wide variety of apparatus in many different arrangements, and while their length may be one of a few values, their width may vary between 1¼ in. and approximately 10 in. For necessary strength the design utilises flat material $\frac{7}{32}$ in. or $\frac{3}{8}$ in. thick. Plates wider than 2 in. usually carry two rows of apparatus or more. A typical plate is shown in Figure 2, from which it may be seen that the mounting provides for three relays of one type and two of another, an induction coil, a retardation coil, two condensers, and an induction coil of another type. While the demand for any one width of plate is small, that for a particular set of drillings in the plate is very much smaller, so that expensive press tools are not justified. It has not, therefore, been possible to improve the manufacturing processes on this class of plate as rapidly as could have been desired, particularly in view of the fact that some of the apparatus mounted on the plates is itself made on mass-production lines. The operations are both slow and expensive; the positions which the apparatus will occupy on the plate must be marked off from one end, and the various holes and slots required for fixing and wiring put in. Frequently these latter operations are little more than handwork, and where resort is had to tools

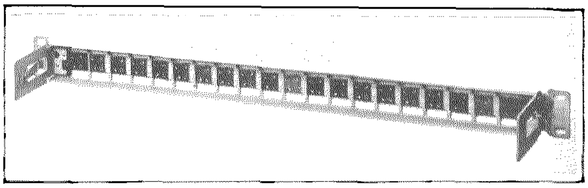


Figure 1—Plate for Mounting Twenty Flat Type Relays Under a Common Dust Cover.

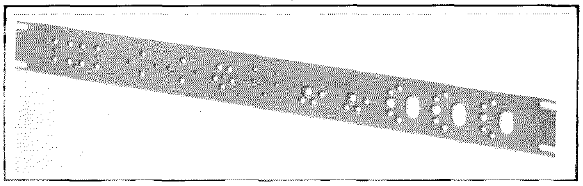


Figure 2—Present Type of Plate for Mounting Mixed Apparatus.

of a less expensive kind the wear and tear is always severe; errors are apt to arise during marking out, which do not become apparent until the apparatus is being assembled on the plate, and there is then no option but to discard the whole mounting plate, a procedure resulting in loss of material and of time.

This last objection leads to a consideration of the second set of difficulties surrounding the $\frac{7}{32}$ in. mounting plate for mixed apparatus, viz., delays in production. It often happens that the drillings required are not known until the order has been received and the major portion of the equipment design work has been finished. It is impossible therefore to forecast any exact information which would assist in making quick deliveries. This uncertainty, combined with the small and varied quantities, makes stock keeping a difficult proposition, with the result that delays, both in ordering and in delivering, are involved. Changes in mounting provisions due to modifications made necessary during the production of the equipment or as a result of factory or field tests may lead to further complications and delays. Similarly, additions or changes during service cannot always be effected; and, if a plate is not fully equipped, the spaces are often left blank.

Attempts have been made in the past to develop a universal mounting plate which would overcome these difficulties, and it has usually been agreed that the plate should consist of one or more crossbars to which can be attached a number of small clips, each clip carrying its own piece of apparatus. The problem, therefore, has resolved itself into one of finding, first, the best shape of crossbar to give sufficient strength to the plate and at the same time involve a minimum loss of mounting space, and second, the simplest means of attaching the clips to the crossbars. Figure 3 illustrates this problem; to the left, there is shown a section of a $\frac{7}{32}$ in. solid mounting plate and, to the right, the problem of the substitution of the equivalent universal mounting plate. The clip (*a*) individual to each piece of apparatus has to be attached to the two crossbars (*b*, *b*), in such a manner that the stiffness of the plate as a whole is maintained; the

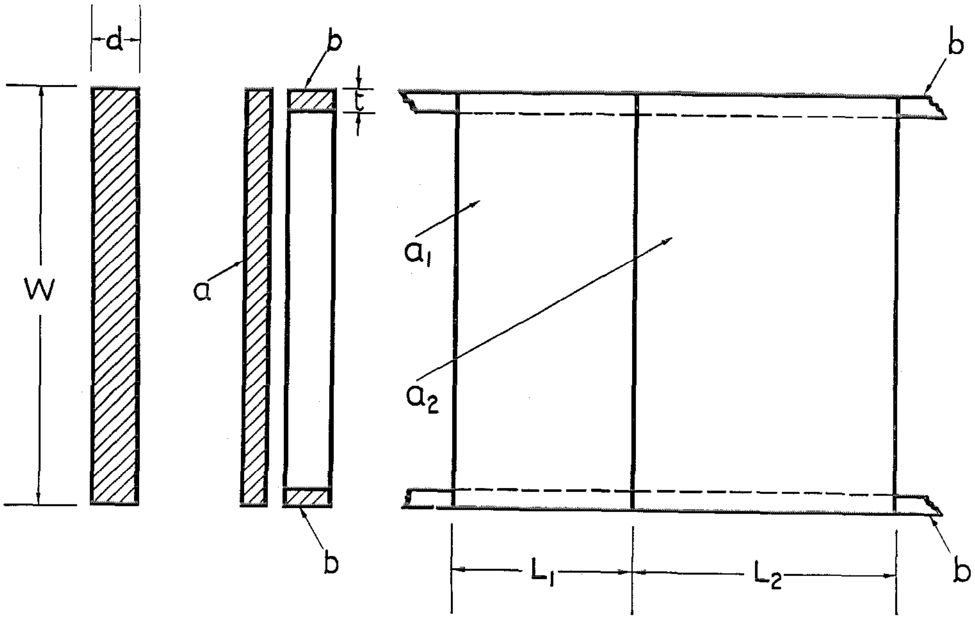


Figure 3—Universal Type of Mounting Plate, Illustrating the Problem Requiring Solution.

loss of mounting space (represented by 2t, the thickness of the bars), is a minimum, and complete flexibility in the assembly of a number of mounting clips (a_1, a_2), side by side, whose lengths (L) may vary according to the shape of the apparatus they have to carry, is attained. It should be noted that the crossbars (*b*, *b*), must be resistant, not only to horizontal and vertical strain, but also to torsional strain set up by the overhang of the apparatus mounted on the plate. This latter condition will not permit the thickness (*t*) of the crossbars to be too small; but, on the other hand, as *t* is increased, the available mounting space is reduced, when this is governed by wiring tags on the outer edges of the apparatus projecting through the plate to the rear. At first sight the simplest way of fixing the mounting clips is to drill and tap a number of holes along the crossbars and to assemble the clips in position by screws. If the thickness (*t*) is small the difficulty of fixing the clip (*a*) becomes more acute on account of the small space available for a screw hole in the crossbar, and the weakening effect which a number of holes will have on the mounting plate as a whole.

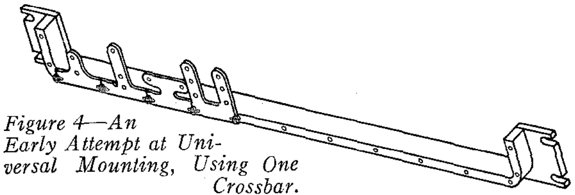


Figure 4—An Early Attempt at Universal Mounting, Using One Crossbar.

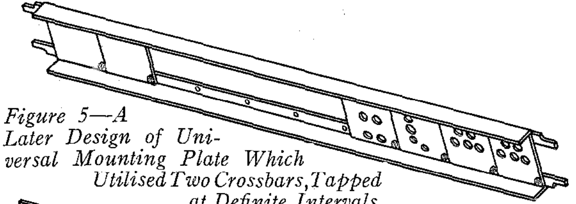


Figure 5—A Later Design of Universal Mounting Plate Which Utilised Two Crossbars, Tapped at Definite Intervals.

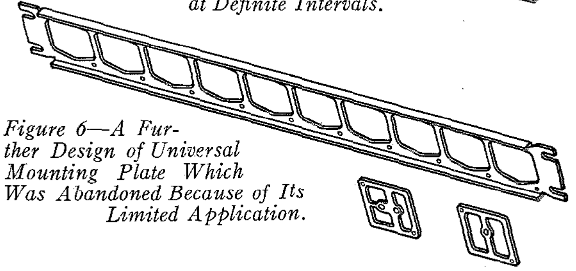


Figure 6—A Further Design of Universal Mounting Plate Which Was Abandoned Because of Its Limited Application.

The earliest proposals for a universal mounting plate followed this principle, and Figures 4, 5, and 6 show how the problems of design were met. In Figure 4 one crossbar was used, and it was intended to reduce the loss of mounting space by combining into one piece the two crossbars whose thickness (*t*) was insufficient to allow for tapped holes of the necessary size; the depth (*d*) was increased above $\frac{7}{32}$ in. to compensate for a relatively small thickness (*t*). This design was abandoned because the mounting clips were apt to become distorted during shipment of the plate due to the weight of the apparatus, a fact which showed that the use of two crossbars, with provision for supporting the clips at the top and bottom, was to be preferred. Figure 5 represents a later design which utilised two crossbars, tapped at definite intervals for screwing on the mounting clips. Figure 6 illustrates a plate of relatively thin material, stiffened by formed flanges at the top and bottom. From this a series of similar "windows" was punched, the "windows" being so proportioned that they would permit the safe mounting of any piece of apparatus with the aid of a particular mounting clip, and without the risk of the wiring tags which project from the rear of the apparatus touching the plate. As with the previous methods, the mounting clips, shown below the plate, were screwed to the plate by the tapped holes provided, each unit lying directly over a "window."

These schemes were abandoned; in common with the first attempt described above, they suffered from the disadvantage of limited application, which arose from the use of tapped holes along the crossbars, since the length (L) of the mounting clips must necessarily conform to the spacing of these holes. For mounting mixed types of apparatus something more flexible was required, so that any length of clip, depending on the shape of the apparatus to be mounted, could be fixed in any position on the bars adjacent to any other length of clip. The screws and tapped crossbars also resulted in a loss in mounting space.

Another proposal, which marks the first departure from the tapped crossbar, is illustrated in Figure 7, where the crossbars (*b*, *b*), are made of U-section and the mounting clips (*a*) are provided with short flanges which enter between the limbs of the crossbars and are held in position by spinning over the outside edges of the crossbars round the backs of the flanges. There was

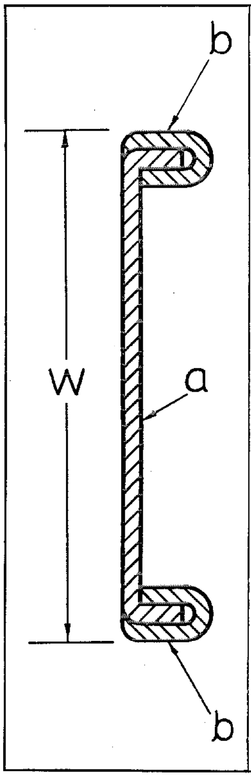


Figure 7 — Universal Mounting Plate—The First Departure From the Tapped Crossbar.

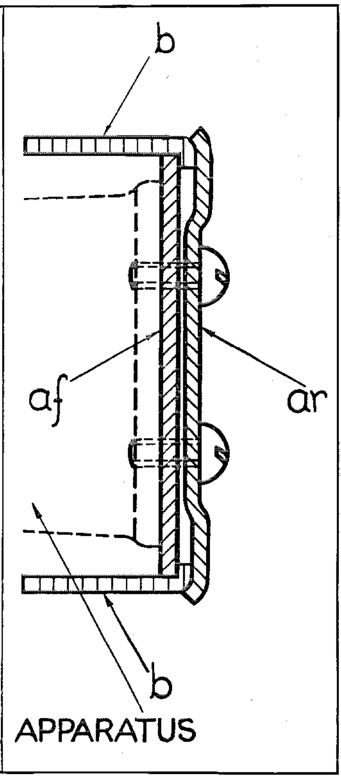


Figure 8—Sectional View Illustrating the Principle of the Universal Mounting Plate Developed by the International Telephone and Telegraph Laboratories.

a serious objection to this design since, without damaging the crossbars, it was not possible to remove or add mounting clips after the assembly had once been carried out. The feature of removing or interchanging clips is of course very desirable. The full mounting width (*W*) was retained in front, but at the back there were three thicknesses of material at the top and bottom, thus reducing the space available for wiring tags and tending to obstruct wiring operations at the back of the plate. However, the design permitted complete flexibility of assembly of different lengths of mounting clips, and to that extent overcame one of the difficulties of the three earlier attempts.

In the Universal Mounting Plate subsequently developed by the International Telephone and Telegraph Laboratories the clamping of the mounting clips to the crossbars has been accomplished in a novel way which overcomes all the difficulties inherent in the earlier designs and which, as will be shown, meets all the requirements outlined above for the second class of mounting plate already referred to. The principle is shown in Figure 8, where a sectional view of the new plate is given. Instead of a single mounting clip being clamped between two parts of the crossbar by a press tool operation, two mounting clips are clamped against a short abutment from a thin crossbar by the same screws which fix the apparatus to the mounting clips; a principle which, while giving complete flexibility as regards assembly of mixed apparatus, permits the quick removal or addition of any piece of apparatus.

The crossbars (*b, b*) are constructed from angle iron, having one long flange, which can be made any length to give the necessary stiffness to the plate, and one short flange, whose length is kept as short as possible, and is just sufficient to act as an abutment for the front mounting clip (*af*). The rear mounting clip (*ar*) is formed inwards about the central portion of its width and also at its extremities. When the two clips are placed in position on the crossbars there is between them a gap of about 0.008 in., which is gradually reduced to zero as the apparatus fixing screw is tightened. This gives sufficient flexing of the clips within the elastic limit of the material to obtain a firm clamp, and also sets a

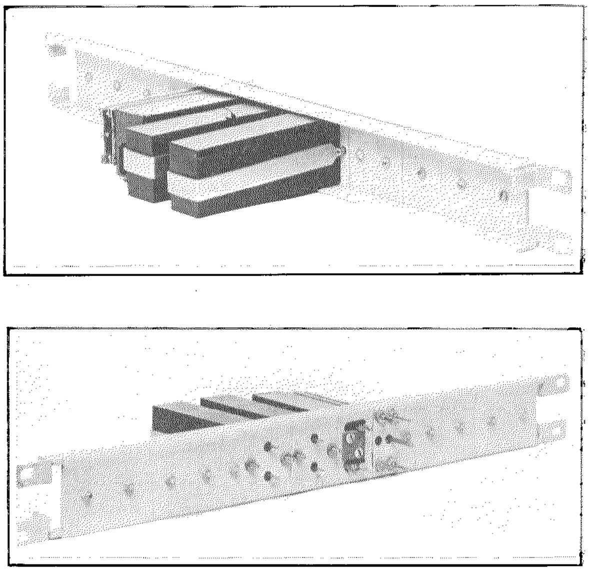


Figure 9—One of the New Universal Mounting Plates Partially Equipped With Mixed Apparatus (Front and Rear Views).

limit to which the fixing screw can be tightened, thus preventing overstraining of the clips. The formed edges of the rear mounting clip bind the two crossbars together on to the front mounting clip which acts as a spacer; and when the assembly is extended along the whole length of the mounting plate it is found that each section of the bars embraced by a pair of clips is maintained in a straight line, so that the whole adequately resists any bending strain which might be set up due to ordinary use. This device is similar to the N-bracing often used in bridge construction.

The apparatus fixing screws perform the dual function of holding the apparatus to the plate, and of clamping the two mounting clips to the crossbars; it is this clamp between mounting clips and crossbars which stiffens the plate as a whole so as very nearly to equal the strength of a solid plate in a vertical direction. Both front and rear mounting clips are pierced with the necessary holes and slots to allow the apparatus to seat on the plate, and, when required, insulating bushes can be pressed into the holes to prevent the wiring tags of the apparatus from touching the frame.

Figure 9 shows a 19 in. Universal Mounting Plate partially equipped with mixed apparatus. It is seen that the unequipped positions are filled with blank mounting clips, the absence of which would reduce the stiffness of the plate, spoil its continuous appearance, and allow free circulation of dust from front to rear. Each crossbar is a separate but similar piece with welded angle pieces at the ends for fixing the plate to the rack in the telephone office. With this arrangement it is necessary to manufacture only one type of crossbar in order to build up any width of single row mounting plate without a dust cover. If a dust cover is required, its supports and spring catches can be made integral with the end angle pieces, as shown in Figure 10, which illustrates a multiple row Universal Mounting Plate built up from unit crossbars of three different types to meet any requirements. Here it is necessary to use means for holding the various crossbars together, in addition to the mounting clips, and a strip of simple section is welded to the various angle pieces at the ends of the crossbars. This spaces the bars correctly and makes the plate sufficiently rigid to mount the full complement of apparatus. The top row is on 2 in. centres; the second, third, and fourth rows are on 1¾ in. centres, and provision is made for a common dust cover to fit over the whole plate. The assembly of either a single-row mounting plate or a multiple-row mounting plate is simple, and the arrangement flexible. The advantages of this construction will be readily appreciated by those who realise the large variety of small-quantity mounting plates which are required in telephone practice.

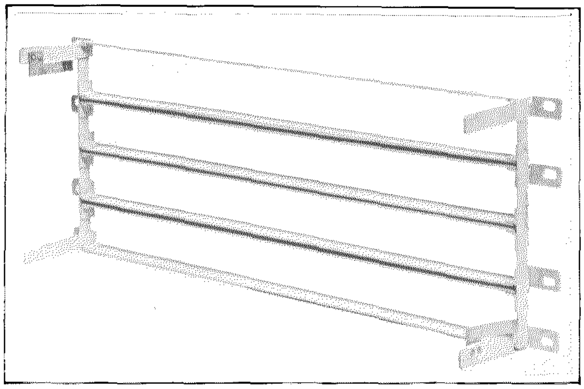


Figure 10—A Multiple Row Universal Mounting Plate Built Up From Unit Crossbars of Three Different Types.

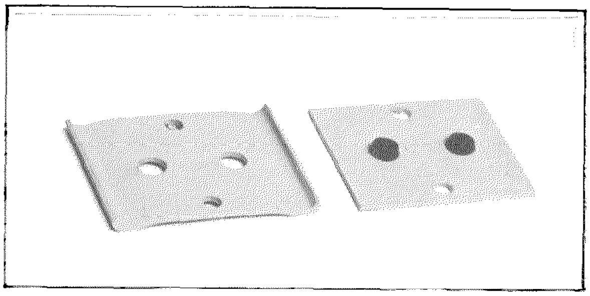


Figure 11—Two Mounting Clips for a Tin-foil Type of Condenser.

Figure 11 shows two mounting clips for a tin-foil type of condenser, from which it is seen that both pieces are simple products of press tools. No fixing screws, other than those usually provided for fixing the apparatus to the plate, are required for assembling these clips on a Universal Mounting Plate.

It is necessary for all clips assembled in one row to be of the same height, but their widths are entirely independent, and are only limited by the total number to be used and the space available for mounting.

Application

The principal application of the Universal Mounting Plate will be the replacement of $\frac{7}{32}$ in. strip plates which are drilled to mount a variety of apparatus. This is so because it is not economical to set up a number of press tools for piercing the different openings in a one-piece plate intended for this purpose. When, however, the mounting plate can be split up into a number of detachable clips, press tools can be justified for its manufacture, because all of a type can be made at the same time.

It is not possible within the limits of a short article to refer to all the applications to which this new development may be put. Certain of the present types of plates for carrying a row of similar apparatus may be replaced by the new design where their annual quantities are small, and where the change would be beneficial. In its present state the Universal Mounting Plate is essentially a developed principle intended to be applied in replacing as many existing designs of $\frac{7}{32}$ in. flat mounting plates as an economic study, embracing all factors, will permit. It can be safely stated that it lends itself to mass-production methods in a way which the present designs are never likely to do, and at the same time it provides a wide degree of flexibility in the arrangement of apparatus during equipment design work and during manufacture, and maintains this virtue throughout its life. With justice, therefore, it can be claimed to be a solution of the problem of mounting miscellaneous apparatus.

IN MEMORIAM

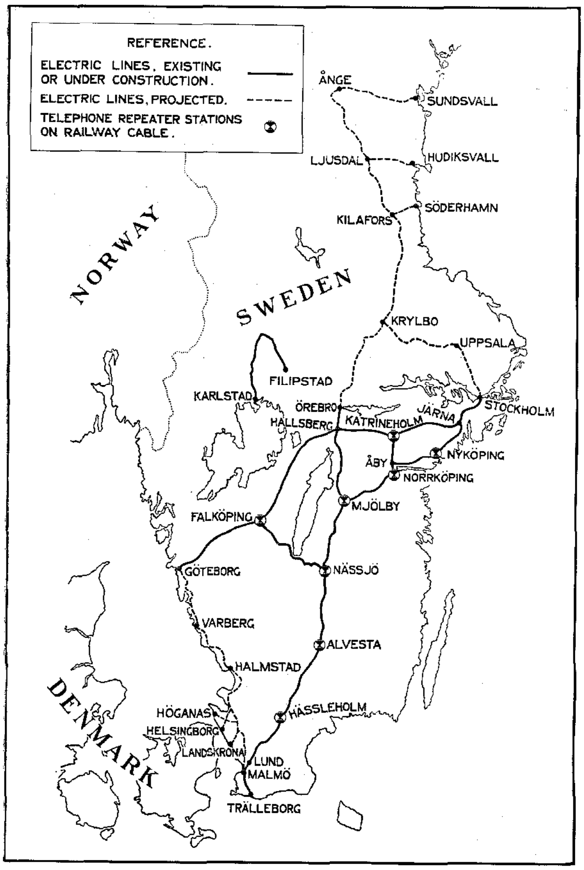
IN the death of Mr. Eduard Otto Zwietusch in an automobile accident, August 8, 1931, the communication industry lost an outstandingly capable and progressive executive, one who served with distinction for over forty-three years. ¶ Born in Milwaukee of German parentage, Mr. Zwietusch retained a fluent command of the German language and an intimate understanding of German life, Americans and Germans both regarding him as one of themselves. ¶ The telephone manufacturing career of Mr. Zwietusch started in 1887, shortly after his graduation from the University of Wisconsin, when he entered the employ of the Western Electric Company, Chicago. He was soon chosen for foreign service and went to Germany as the directing head of E. Zwietusch & Company, Charlottenburg, Salzufer, at that time an associated company of the Western Electric Company. In 1904 he became a German citizen. ¶ Due to his untiring energy and his marked ability in connection with technical and manufacturing problems, he was in a short time able to develop the company into a flourishing concern. In co-operation with the Reichspost he developed important changes and innovations in the telephone field which were quickly introduced by the German Reichspost. ¶ While essentially a technical man, he was equally at home in the manufacturing and commercial field. One of his hobbies was the design of apparatus using punched parts entirely, and no punching was too intricate or difficult for him to attempt. In the earlier days it must be remembered that telephone apparatus was made up of many small parts riveted together and even of small castings. ¶ Until 1921 Mr. Zwietusch guided the undertaking at Salzufer. Thereafter until 1926 he looked after interests of the International Western Electric Company, now the International Standard Electric Corporation. In January, 1927, he was made Director General of the Vereinigte Telephon-und Telegraphenfabriks Aktien-Gesellschaft, Czeija, Nissl & Co., Vienna, and in 1930 he became Managing Director of the Telephonfabrik Berliner A. G., Berlin-Steglitz. At the time of his death he was Director General of C. Lorenz A. G.

His noble, simple, and kindly manner, his consideration towards everyone and his readiness to help wherever he could, secured for him the love, respect, and confidence of all his colleagues. Both in Europe and in America he leaves a large circle of friends who mourn his premature death.

Stockholm-Malmö Railway Cable

IN *Electrical Communication*,* Vol. IV, No. 4, Mr. Ivar Billing, Byrådirektör in the Swedish Railway Administration, contributed an article on the telephone cable, which had then been installed along the railway between Stockholm and Göteborg, a distance of 458 km. The main reason for placing the telephone circuits in a cable was to protect them against any disturbance from the electric power circuits, used in the operation of the railway.

Electric traction is being used to an increasing extent on the railways in Sweden, as will be seen from the accompanying map. The present length of electrified line is over 900 kilometres, divided almost equally between the northern and southern sections, only the southern section being shown on the map. The rate at which further electrification is planned is that by 1937 or 1940 the total electrified line will be 2,900 kilometres, which represents some 40% of the entire railroad system. In general, a new telephone cable has to be installed as each section of line becomes electrified. A short time ago, the Swedish Parliament sanctioned the electrification of the important section from Stockholm to Malmö, with several tie lines to the Stockholm-Göteborg line and an extension to Trälleborg, which is the railhead for the railway traffic with the continent of Europe. This work is now under way and simultaneously a telephone cable over the same route is being installed. The aggregate length of cable involved is 936.3 km. of various types, particulars of which are given in the table below:



Section	Distance Km.	Type of Cable
Stockholm-Malmö....	613.3	3 quads 1.4 mm. conductor 10 quads 0.9 mm. " 2 pairs 1.4 mm. "
Myölby-Orebro.......	125.0	3 quads 1.4 mm. conductor 16 pairs 0.9 mm. "
Nassjö-Falköping.....	115.0	3 quads 1.4 mm. conductor 16 pairs 0.9 mm. "
Norrkoping-Katrineholm.......	49.8	3 pairs 1.4 mm. conductor 12 " 0.9 mm. "
Malmö-Trälleborg....	33.2	3 pairs 1.4 mm. conductor 12 " 0.9 mm. "
Total............	936.3	

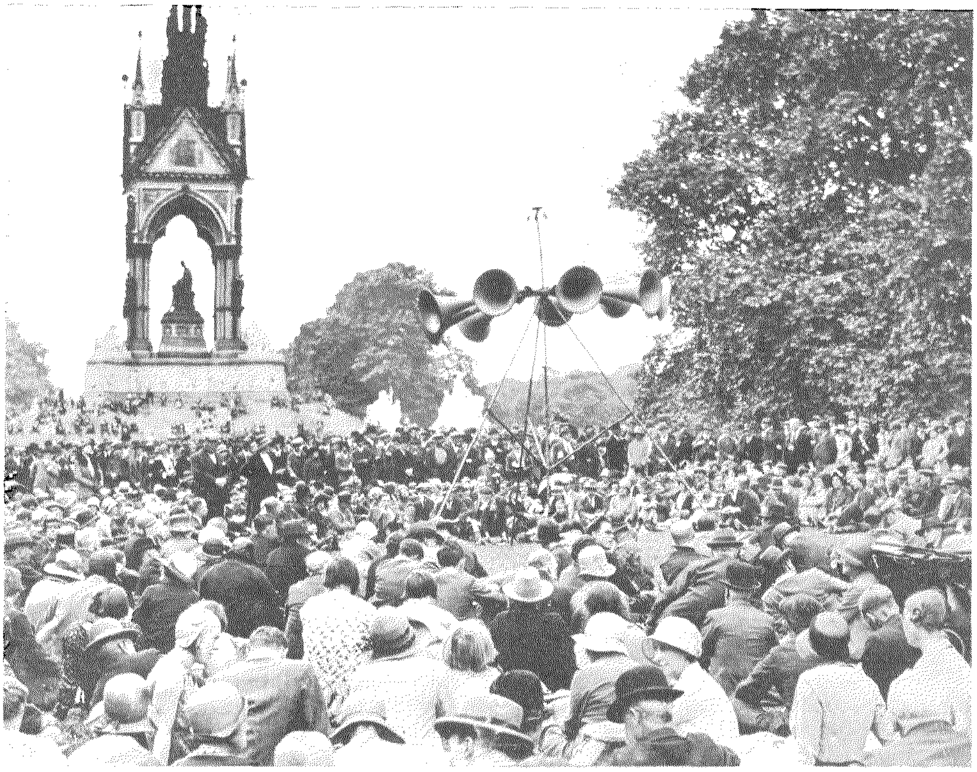
The cable is of the usual telephone type, paper insulated, lead covered and lightly armoured but capable of withstanding a somewhat higher breakdown voltage between conductors and between core and sheath than cable installed in positions free from the danger of interference from electrical power systems. The mutual capacity between wires and pairs is also lower than in normal cables. Loading coils will be installed throughout on a spacing of 2,200 m. to provide the required attenuation and cut-off characteristics. The quadded circuits will be loaded with 160 mH side and 63 mH phantom coils or 177 mH side and 63 mH phantom coils, whilst the paired circuits will be loaded with 160 mH or 177 mH coils.

---

* "Stockholm-Göteborg Railway Cable," April, 1926.

Since the cable circuits for certain distances are of such length that loading alone will not give the desired transmission equivalents, the necessary telephone repeaters will be installed in six stations along the route.

The cable is being manufactured by Sieverts Cable Works, Sweden, a company working under a license from the International Standard Electric Corporation in the long-distance cable field. The repeater station equipment is being made by the Standard Telephones and Cables, Limited, of London.



The demand for tickets for the National Disarmament Meeting on July 11, 1931, at Albert Hall, was so great that an overflow meeting had to be held in Kensington Gardens, the speeches being relayed by means of the Public Address system of Standard Telephones and Cables, Limited, London. The photograph shows the crowd gathered around the loud speakers near the Albert Memorial, listening to the speeches.

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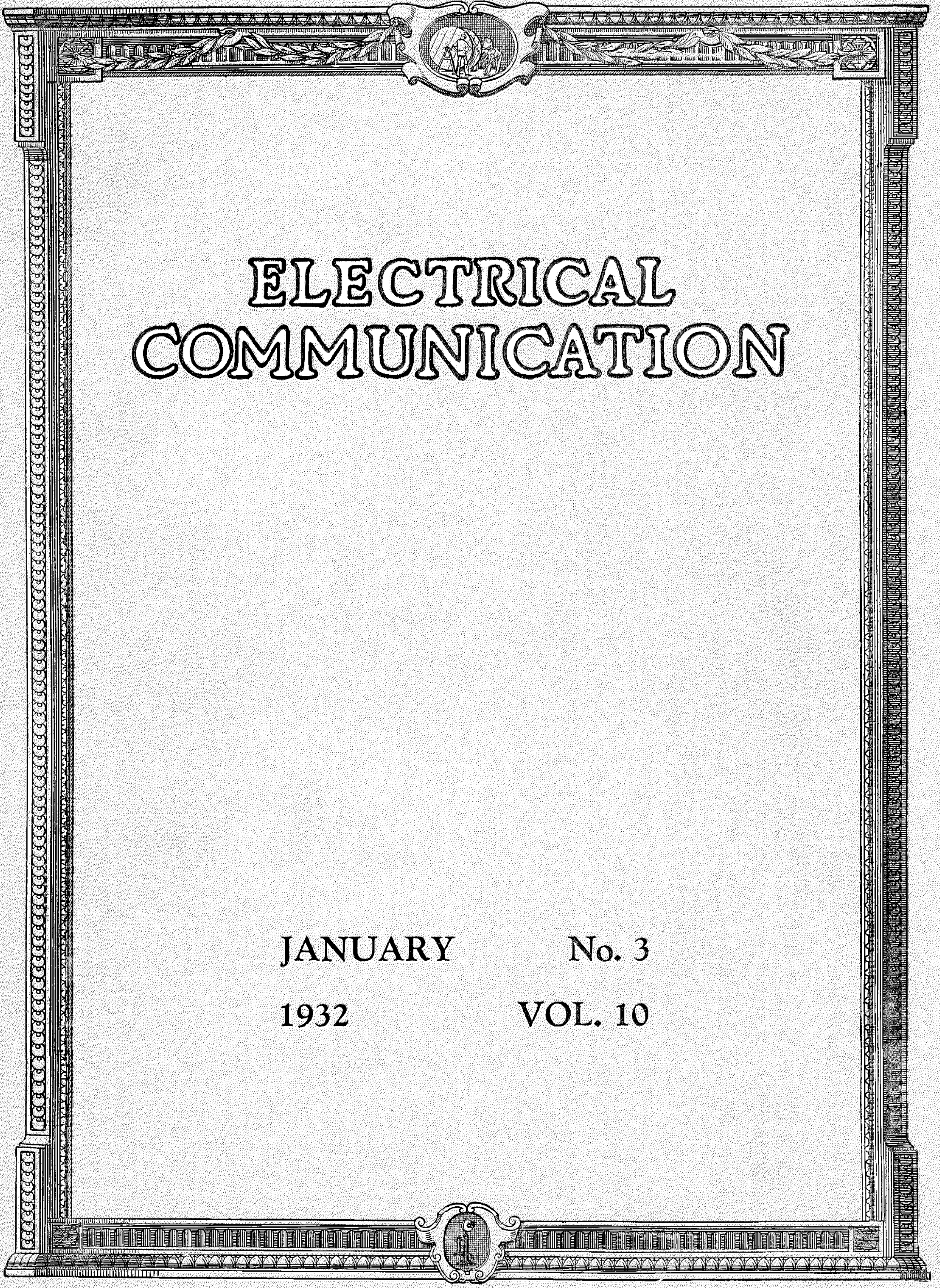

ELECTRICAL COMMUNICATION

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ELECTRICAL COMMUNICATION

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CONTENTS

PAGE

Electrical Communication in 1931 101

The Prague High-Power Broadcasting Equipment 106
By D. B. Mirk, B. Sc.

Lining Up Broadcasting Circuits 131
By E. K. Sandeman

Pneumatic Ticket Distributing Systems for Toll Boards 134
By Carl Beckman

A Brief Biography of Mr. Kankichi Yukawa 139

An Automatic Device for Recording, Correcting and Analysing Articulation Results 140
By John Collard, Ph. D.

Modern Loading Equipment 147
By J. B. Kaye

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Electrical Communication in 1931

Radio Telephony

RAPID progress in extending international radio telephone services in 1930 was continued in 1931. New direct radio telephone services inaugurated include Argentina, Chile, and Uruguay on the one hand and Australia on the other, followed by extension of the Australian international service to the whole of that continent and to New Zealand. Chile was directly connected to Spain, and the Canary Islands and Mallorca Island were also linked to Spain and by existing land wire and radio systems to Europe and North and South America and Northern Africa. Radio telephone service was started between Colombia (South America) and Argentina, Chile, Uruguay, and all European points served by the Compania International de Radio (Argentina); also between the United States and Bermuda and the Hawaiian Islands. In the latter case an inter-island radio telephone service was inaugurated.

So-called tandem circuits were established between North America and Java through intermediate stations at Amsterdam and Berlin and links were inaugurated between Java and Australia, Java and Sumatra, and Java and Siam.

Through utilisation of existing radio telephone circuits, many additional land line systems were connected with those of other countries during the year. Principal among them were the connection of the United Kingdom telephone network with Indo-China, Morocco, and New Zealand; North and South America with Rumania and Esthonia; Sweden with Indo-China, Siam, Java, and Australia; Finland with Java; Belgium with Siam; Germany with Indo-China; Latvia with Siam and Java; Czechoslovakia and Luxemburg with Siam and Indo-China; the Netherlands and Hungary with Indo-China; Austria with Indo-China and Siam; Switzerland with Morocco, Indo-China and Siam. Radio telephone connection was also established between Italy and Sardinia.

Through Companhia Radio Internacional do Brasil, an associated company of the International Telephone and Telegraph Corporation, the network of the Brazilian Telephone Company was connected with the networks in the United States, Canada, Mexico, Cuba, Argentina, Chile, Uruguay. Connection with Europe either will have taken place before this issue of *Electrical Communication* reaches the reader or will be effected shortly thereafter.

Stations under construction will provide for service between the United States and Japan. Arrangements are under way for telephone service between Great Britain and India, Africa, and Egypt.

On March 31, 1931, a demonstration of two way radio telephony, working on an 18 cm. wave length, was given between Dover, England, and Calais, France. Upward of 30 guests assembled on each side of the Channel and took part in conversations across the Straits of Dover. The system used, known as the Micro Ray, employs an antenna only 2 cms. in length. It has been found that waves of this length do not fade as do ordinary waves nor are they absorbed by rain or fog as are light waves. Other advantages of the system include the making available of nearly one-quarter of a million Micro Ray channels even if each transmitter were to differ in wave length to the same degree as is now necessary with ordinary transmitters.

During the years 1930-1931 the International Telephone and Telegraph Laboratories, Hendon, England, in conjunction with the Laboratories of Le Materiel Telephonique, Paris, France, carried out a series of tests on the single side band system of radio telephony applied to short wave lengths. The results show definitely that there has been evolved one system of single side band working applicable commercially to short wave links. A demonstration of this system was given on May 21, 1931, between Madrid and Trappes, near Paris. Over 70 guests listened for a period of approximately one hour to transmission of speech in English and French and of signals designed to show the degree of synchronisation between the suppressed carrier at Madrid and the re-supplied carrier at Trappes.

A spread side band system for use on short wave telephone links has been developed by means of which distortion effects due to selective fading in particular can be reduced or eliminated. By an extension of the principles involved a number of side bands can be placed on one carrier in such relative positions to each other and to the carrier that "harmonic distortion" as well as crosstalk between the various communication channels is eliminated.

A tube having exceptionally small clearances between the electrodes, known as the Micromesh, was developed during the year. It has an extremely high gain and much better characteristics than tubes heretofore available.

In the field of mobile communications, existing telephone services available to ships at sea from most American and European telephone subscribers have been extended to the new Canadian Pacific Railway liner "Empress of Britain," and from American telephones to the Furness liner "Monarch of Bermuda." The S.S. "Belgenland" on its world tour made some striking records in transoceanic telephone contacts. The first was a nation-wide broadcast by Professor Einstein and others from New York Harbor. The next came from the Pacific Ocean off the coast of Central America. Other telephone connections established were from Chinese waters to the United States, Bombay to London, the Red Sea to the United States, and Alexandria, Egypt, to Washington.

Long Distance Telephony

The European Toll Cable network is a vast framework of loaded cable and repeaters linking up practically all the important towns in Europe, running as far east as Warsaw and Budapest and extending further east by open wire line into the Baltic countries, Russia, Rumania, Yugoslavia, Bulgaria, etc. This great system has been an accomplished fact for some years, the long distance circuits being capable of extension to practically every corner of the countries throughout which it extends. As the national and international traffic over the circuits provided by the network increases from year to year, additional cables are laid, either paralleling existing cables or replacing outlying open wire sections or extensions. In some cases a cable network has been constructed in an outlying country temporarily linked to the main network by open wire lines, the open wire link to be replaced by cable as soon as the traffic warrants. An important cable link of this nature was completed during 1931, which now extends the cable network to Warsaw. A similar cable link was inaugurated during 1931 in Italy where the network north and south of Rome has been connected to the North Italian network and thus to the main European network.

Some appreciation of the work involved in paralleling and extending the European network can be obtained from the fact that cable approaching 5,000 kms. in length and containing over one million kilometers of copper conductors, was added during 1931. Although this figure is lower than for 1930, the work done by the International Standard Electric Corporation's associated manufacturing and affiliated cable companies in providing cable, loading coils and repeaters was almost if not quite as great as for 1930. As an illustration, the loading coils supplied by associated factories in Europe may be mentioned. In 1930, the number of coils supplied was just under a quarter of a million, whilst for 1931 the figure had reached 215,000 early in November.

Outstanding events during the year include the completion of the London-Liverpool cable, where the early obsolete cable was withdrawn and replaced by a modern cable with a minimum of traffic dislocation; the inauguration of the Hongkong-Canton cable, when a demonstration of picture transmission and teleprinter operation, over the cable, was given and the above mentioned inauguration of the Italian State Cable completing the link with Rome, both to the north via the northern Italian system to Switzerland and to the east into Austria.

A special feature of the Long Distance Cable systems installed during 1931 is the inclusion in most cases of special circuits for the handling of broadcast transmission, these circuits being specially designed to meet these conditions and including very high grade repeaters capable of transmitting the necessary broad band of frequencies with negligible distortion of any kind.

An important development on the part of the International Telephone and Telegraph Laboratories, Hendon, England, in 1931, was a 4-wire voice frequency carrier telegraph system for use in telephone cable circuits operating on a band width of 120 cycles as against 170 cycles for the earlier system. Through the contraction of the band width it has been possible to increase the number of channels from 12 to 18. The British Post Office plans to install this new equipment and other Administrations have expressed interest in it.

Repeater Equipment

Considerable progress has been made towards reducing the space occupied by repeater equipment, a notable advance in this direction having been made by the International Telephone and Telegraph Laboratories' development of the new type small repeater equipment. In addition to improved performance, the space occupied is approximately half that required by previous types so that the capacity of a given floor area is practically doubled.

European Administrations are making very extensive use of repeaters over short lines rather than laying down heavy copper circuits. The developments of the International Telephone and Telegraph Laboratories have contributed in no small measure to these contracts by providing the so-called "junction repeaters."

Interference

Rapid developments now taking place in power transmission lines and electrified railways, as well as in communication systems, are causing European and other Administrations to take increasing interest in the question of interference. To meet this growing demand a special department of the International Telephone and Telegraph Laboratories has been formed for the purpose of developing special technique for handling interference problems and for consultation both regarding the amount of interference to be expected under given conditions and the method of overcoming such difficulties.

Automatic Telephony

New automatic exchanges were opened in many countries of the world including Mexico, Peru, Honduras, Argentina, England, France, Spain, Norway, Hungary, Switzerland, Czechoslovakia and Russia. In cities such as Istanbul, Cairo, and Shanghai where automatic installations were inaugurated, multi-lingual telephone problems incident to a population speaking a number of languages were greatly alleviated. Many of the exchanges installed were of the rotary type built in factories forming the International Telephone group. Incidentally, during the year an accord was reached between the International Telephone and Telegraph Corporation and Telefonoaktiebolaget L. M. Ericsson of Sweden.

A new small automatic private branch exchange has been made available which permits free interconnection between the various local stations in business establishments and residences. Such connections are set up entirely automatically. In addition, any or all of the local stations may secure outside connections by appropriate dialing. Incoming calls are handled by an attendant who has facilities for transferring a call to any of the local stations.

Substation Equipment

It has long been a problem to provide neat appearing telephone sets that will withstand the heat and moisture of the tropics. This problem has recently been solved by molding the entire outer casing of the telephone of phenol plastic, thus effectually removing for all time the possibility of finish troubles. A further improvement has been effected in substation equipment through the development of an anti-side tone circuit which permits the use of a more efficient transmitter and a lowering of the noise level resulting in the aggregate of a gain in overall efficiency and clarity.

Radio and Wire Telegraphy

On December 1st there was placed in operation, in the International Telephone Building, 67 Broad Street, New York, one of the world's largest and most up-to-date cable and radio operating departments. It serves jointly the Commercial Cable Company, the Mackay Radio and Telegraph Company, and All America Cables. Circuits which link the United States with Europe, Central America, South America, and the Far East terminate therein, and connect 85,000 miles of undersea wires of International communications through 19 separate channels.

Greatly improved service and reduced operating costs in handling messages received in the main operating department from branch office printers has been obtained through the use of automatic printer concentrators. These concentrators serve as automatic switchboards which enable a branch office printer operator to obtain practically instantaneous connection with an idle printer in the main operating department. As a result of the speed with which connections are established, the efficiency of the main office operating staff is greatly increased.

Three of All America's cables to Central and South America, and two of the fastest New York-London cables of the Commercial Cable Company have been equipped with recently developed printer apparatus. These printers have greatly increased the accuracy of reception due to the elimination of human errors at the receiving stations and have effected substantial staff economies.

As a result of the development and application of rotary repeaters and special terminal apparatus, the speed of the fastest of the Commercial Cable Company's Atlantic cables was increased 30% and converted to two-channel operation.

Carrier current telegraph equipment, little used heretofore in purely telegraph plants, shows evidence of wider future application in this field of service. During the year the Postal Telegraph-Cable Company, for example, placed in service between New York and Washington a new 10-channel, 4-wire voice frequency system. Each of the ten channels carries a 2-channel multiplex circuit in each direction, thus adding 40 one-way telegraph circuits to the capacity of the lines on which the equipment is installed. The performance of the system has been so satisfactory that plans are being made for extending the use of this type of carrier operation.

The Postal Telegraph-Cable Company and the Western Union Telegraph Company announced on November 20th, the inauguration of Timed Wire Service which is available to every printer installed in the customers' offices of either Western Union or Postal Telegraph. As a result of this new service, the same instrument operated by the same operator who has been sending and receiving telegrams for the customer can be used also to send Timed Wire Service to any customer of either company who has a printer installed in his office. The new service is charged for on a time rather than a word basis and messages are delivered over the lines of either of the telegraph companies to any addressee who has a teleprinter in any part of the United States. A directory of all telegraph printer customers of both companies has been published jointly by the two telegraph companies and shows the great scope and ramifications of this new service.

An automatic printer switching system has been developed with which it is proposed ultimately to place Timed Wire Service on an exchange basis similar to that of the automatic telephone exchange.

As a result of the general demand from European Administrations, the International Telephone and Telegraph Laboratories, Hendon, England, for the last several years has been working on systems which provide for special teleprinter exchanges or alternatively, switching at voice frequencies over ordinary subscriber's telephone lines. In line with this development the British Post Office have ordered from Creed & Company, Limited, 500 7-A teleprinters for the purpose of establishing, early in 1932, a printer switching service by means of the existing telephone exchange network to any telephone subscriber in Great Britain on payment of £65 per annum with the provision that a subscriber desiring this service must have a second telephone circuit in order that one will be available for telephone purposes while the teleprinter is in use.

In addition to the submarine cables terminating in the new cable operating department at 67 Broad Street, New York, the Mackay Radio and Telegraph Company has set up 24 radio positions providing direct contact with Europe, South America, the Far East, ships at sea and connecting the Atlantic with the Pacific by a direct transcontinental radio route.

New radio telegraph circuits from the United States to Cuba, Colombia, Austria, Czechoslovakia and China, were inaugurated in 1931, either by Mackay Radio and Telegraph Company or the R.C.A. Communications, Inc. Other important new circuits opened included Paris-Shanghai, Paris-Teheran, Berlin-Teheran, Buenos Aires-Brussels, Buenos Aires-Asuncion (Paraguay), Shanghai-Bangkok, Dairen-Osaka, and London-Nairobi (Kenya, East Africa).

The German Luft Hansa Company during the year offered to the air traveling public the first regular plane-to-station radio telegraph service.

In passing, it may be of interest to note that the automatic printer concentrator, the automatic printer exchange system, the cable printer, the rotary repeater and special terminal apparatus for increasing speed and providing 2-channel cable operation, and the carrier current telegraph equipment referred to above were all developed by the International Communications Laboratories, Inc., New York, a subsidiary of the International Telephone and Telegraph Corporation.

Broadcasting

International and transoceanic radio broadcasts improved greatly in quality during the year and the increase in chain broadcasting by means of remote control radio circuits was notable. In addition to transatlantic nation-wide broadcasts over remote control circuits, similar broadcasts, for example, occurred from Buenos Aires, Rio de Janeiro, and the Hawaiian Islands. Outstanding individual broadcasts included the speech of the Prince of Wales from Buenos Aires during his visit to Argentina, and the United Press broadcast from Tokyo to the United States. An interesting nation-wide program was broadcast from Havana where a submarine cable circuit of the Cuban American Telephone and Telegraph Company served as the connecting link between Cuba and the United States.

The Prague broadcasting station was completed in 1931. It is a 200 kw. station according to the latest C.C.I.R. rating and is the largest station now in operation in the world. It was supplied and installed by Standard Electric Doms a Spolecnost, Prague, in accordance with the designs of the International Telephone and Telegraph Laboratories, Inc.

During the year two installations were made of a new type of antenna for radio broadcasting. These antennae consist of a single fabricated tower with one set of guys at about the half way point. The whole tower rests on a single insulator and acts as a vertical antenna. The towers so far constructed have been designed to have a height about 0.6 of the operating wavelength. The intensity of the signal strength over a wide coverage is in the neighborhood of 40% greater than that of the standard type ¼ wavelength antenna. Studies of the application of this type of antenna are being continued.

The Prague High-Power Broadcasting Equipment

By D. B. MIRK, B.Sc.
International Telephone and Telegraph Laboratories

THE Prague High Power Broadcasting Station lies some 35 kilometres east of Prague in the vicinity of the small town of Cesky-Brod. The surrounding country is practically flat with the exception of a few small hills three to four kilometres distant from the station.

The fundamental requirement governing the choice of site was of course the necessity of having a good field strength in Prague. Then, owing to the geographical shape of the country, it was desirable that the station should be east of Prague. Further requirements were a suitable power supply near the site and good transport facilities. A series of field strength measurements made by the engineers of the Czecho-Slovakian administration in collaboration with the engineers of the International Telephone and Telegraph Laboratories indicated that the Cesky-Brod site would give good crystal reception in Prague. Furthermore, this site had available a 15,000 volt, 3 phase, 50 cycle power supply actually passing over it, and good railroad transport was available. Figure 1 shows the site with the masts and the building erected.

The complete radio broadcasting equipment was supplied and installed by Standard Electric Doms a Spolecnost, Prague, to the designs of the International Telephone and Telegraph Laboratories, Inc. It is, according to the latest C.C.I.R. rating, a 200 kw. station and is probably the largest broadcaster now operating in Europe. The equipment is of the most modern design giving very high quality reproduction, with an overall power efficiency of the order of 22 per cent. It employs 40 kw. thermionic valves working on an anode tension of 20,000 volts, supplied from a mercury arc rectifier. The equipment is installed in a two-story building, and is laid out as shown in Figures 2 and 3, the radio transmitter being installed on the upper floor and the power equipment on the ground floor. The antenna is supported by two 150 metre insulated self-supporting masts spaced 250 metres apart.

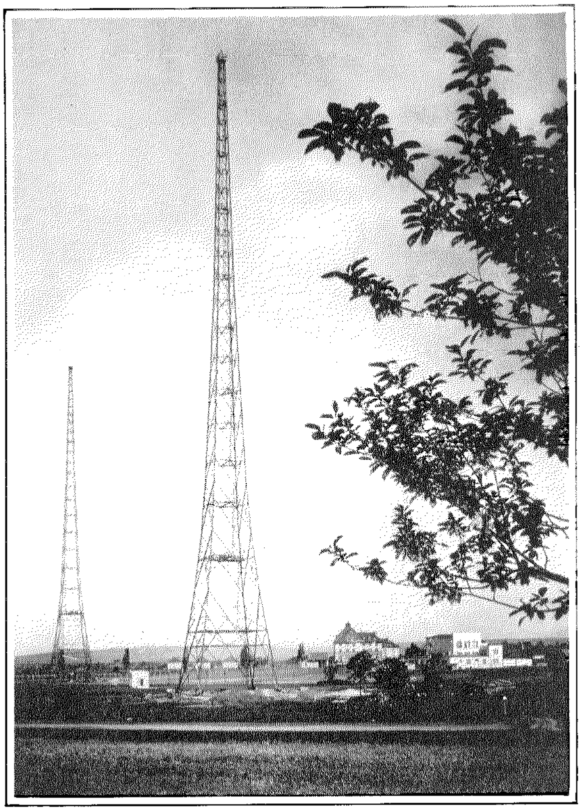


Figure 1—Prague High-Power Broadcasting Radio Transmitter Site.

Briefly, the requirements of a high power modern broadcasting equipment may be summarized under two headings: technical and economic. Technically, the system must give a programme of the highest quality. Economically, the running and maintenance costs must be low. The design of the broadcasting equipment for Prague has been influenced fundamentally by these two requirements.

The complete broadcasting system may be considered as comprising the speech input equipment (which is generally located in a studio at some distance from the radio transmitting equipment and is connected by telephone lines to the line amplifier equipment located at the radio transmitter), the radio transmitting equipment, and the antenna system.

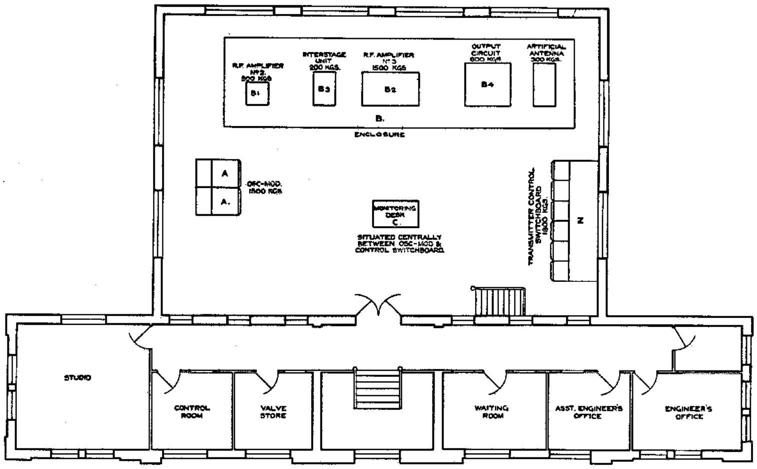


Figure 2—Layout of Building— Upper Floor.

All dimensions shown are in metres. Windows marked "a" to be fitted with bars. Doors marked "b" are locked by special safety keys.

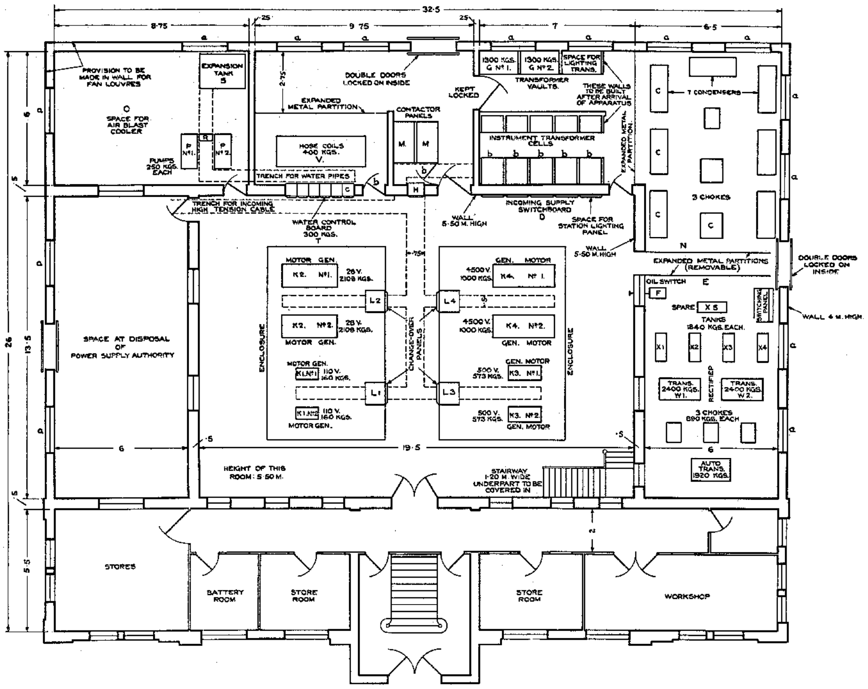


Figure 3—Layout of Building—Ground Floor.

The Speech Input and Line Amplifier Equipment

The speech input equipment is designed to cater initially for two studios, with provision for extending up to ten studios by the addition of further studio equipment. It is designed to utilise two high quality condenser microphones and one carbon microphone in the first studio; and one condenser microphone and one carbon microphone in the second studio. It also provides the apparatus for a central announcer and controller with a possibility of adding a further small amount of apparatus to introduce echo effects. The controls provided give the possibility of "mixing" the outputs of the various microphones in the studio, in any desired proportion, and also of mixing the output of another studio or of the announcer microphone with the output of the studio microphones.

The signalling equipment enables the announcer in the control position to warn any of the studios that the microphone is to be switched on, and to switch on the warning lights inside and outside the studio from which the programme originates. Facilities are provided for taking a programme from a number of outside lines, and attenuation networks are fitted for obtaining the correct input level to the amplifier. The whole of the equipment, with the exception of the microphone batteries, is operated from the supply mains by means of dry metal rectifiers and smoothing circuits. For the microphone and the first microphone amplifiers, batteries charged by motor generator sets are employed.

In the control room the equipment is mounted on racks. One of these contains the microphone amplifiers and mixing panels. A second rack houses the main amplifier with the monitoring and gain control facilities. A third rack contains the radio receiver which is so installed that the quality of the transmission from the radio station may be checked up with the quality at the output of the microphone amplifier; it also contains power amplifiers for feeding a number of moving coil loud speakers installed at various waiting rooms and offices throughout the studio building. A further bay of racks carries the power supply equipment.

The total gain of the speech input equipment is 75 decibels. The frequency characteristic is practically straight from 30 to 10,000 cycles. The equipment is capable of delivering an undistorted output of plus 16 decibels, into an output impedance of 500 ohms.

The radio transmitter is situated about 35 kilometres from the studio, and the connection between the two is made by underground cable. This arrangement causes considerable speech attenuation and in order to bring the speech back to a suitable level for modulating the radio transmitter, a line amplifier equipment is installed. This consists of a two-stage amplifier fitted with gain control and facilities for the use of a local microphone. An equaliser panel is supplied in order to equalise the line so as to have a characteristic as nearly flat as possible between 30 and 10,000 cycles. The amplifier is provided with a meter panel, a volume indicator, and a monitoring amplifier panel. The complete equipment is operated by rectifiers and from the mains, and includes all the switches and apparatus necessary for the use and control of this power plant. Included with the equipment is a moving coil loudspeaker and a carbon microphone. A microphone amplifier panel is also provided to bring the output of the microphone up to the same level as the output of the underground cable. A jack panel is provided so that the input of the line amplifier may be connected to any of a number of incoming lines. The whole of the apparatus is mounted on standard relay racks.

Description of Radio Transmitter

As the advantages of 100 percent linear modulation are now well appreciated, they will not be enumerated here. It is sufficient to point out that modern broadcasting demands equipments capable of 100 percent modulation. Provided Heising or choke control modulation is used, it is well known that the technical difficulties in obtaining "straight line" or distortionless modulation are now practically limited by the power capacity of the valves in the last amplifier stage. With 100 percent modulation the peak power given by the valves is four times the normal carrier power. With modern technique the peak power capacity of the valves in the final stage of amplification, therefore, may be considered as the only factor limiting the power output of the radio transmitter.

The broadcaster is designed to be capable of 100 percent distortionless modulation when delivering 120 kilowatts of carrier power to the antenna, that is to say, the power which can be delivered by the valves in the final stage feeding the antenna is 480 kw. Within the limits imposed by the power supply equipment the carrier power can, of course, be raised at the expense of a reduction in the distortionless percentage modulation. Actually, the power supply equipment has been designed to be capable of giving a power of 150 kw. carrier with 80 percent distortionless modulation.

The radio transmitter has been designed to have a frequency characteristic such that the variation in transmission efficiency over the whole radio frequency range from 30 to 10,000 cycles does not exceed 3 decibels. Departures of this magnitude from a straight line characteristic cannot be detected by the ear.

For the purpose of this description the radio transmitter will be considered under three main sections: (1) The radio transmitting equipment, which comprises all of the apparatus associated with the generation of the radio carrier frequency, its modulation with the telephonic currents received from the line amplifier equipment, and the amplification of the resultant modulated wave to the required energy for delivery to the antenna system; (2) the power plant, which includes all the apparatus necessary for accepting a supply of commercial power from the incoming feeder, controlling this power and converting it into the special forms required to feed the radio transmitting equipment; (3) the water cooling system comprising the means for circulating the cooling water and dissipating the heat which it acquires from the valves.

THE RADIO TRANSMITTING EQUIPMENT

The system is one of modulation at low power with subsequent high frequency amplification. The carrier power is generated in a low power frequency controlled master oscillator, which provides the sole drive for a succession of non-regenerative amplifier stages. Modulation takes place at a slightly higher level than the master oscillator output. Special provision is made to prevent frequency modulation, with resulting distortion, as a result of any reaction on the master oscillator, through valve capacity or otherwise, from the modulated amplifier or the radio frequency amplifiers.

The crystal controlled master oscillator drives a neutralised amplifier or first coupling stage. All the following amplifier stages are of the balanced push-pull type. The second coupling stage feeds the modulator amplifier, which is followed by three stages of radio frequency amplification. The use of balanced push-pull circuits throughout gives practically complete freedom from reaction, and thus avoids the possible distortion of the straight load characteristics of the amplifiers. It also enables the equipment to be adjusted and tuned very easily as each circuit is entirely independent from the point of view of tuning, and is consequently not affected by any changes made in the adjacent circuits. In order further to improve the stability, "anti-singing" resistances are provided in all plate and grid circuits. As is well known, the value of the grid filament impedance of a "3rd class amplifier" changes greatly, depending on the driving voltage applied. Consequently, it is necessary to "swamp" this varying impedance by another impedance of a value much lower than the minimum value of the grid filament impedance. This consists of a resistance which is connected across the filament grid circuit of the amplifier valves. Furthermore, to prevent the tendency to spurious oscillation, large values of capacity are connected directly across the grid and filament of each valve. Lastly, even in a perfectly balanced push-pull circuit trouble is often met, due to "parallel oscillations," i.e., oscillations which pass via the grid chokes through the two valves in parallel and return via the anode chokes to some point of a common high frequency potential. These oscillations are prevented by the incorporation of resistances in series with the grid and anode chokes and large by-pass condensers on each choke. By these means, therefore, an equipment has been produced which has no reaction, is absolutely stable and free from spurious oscillation, and whose carrier frequency is therefore determined solely by the frequency of the master oscillator.

As is well known, the anode current of a third class amplifier valve varies at audio frequency. Consequently it is necessary that the circuit supplying the anode current to these valves

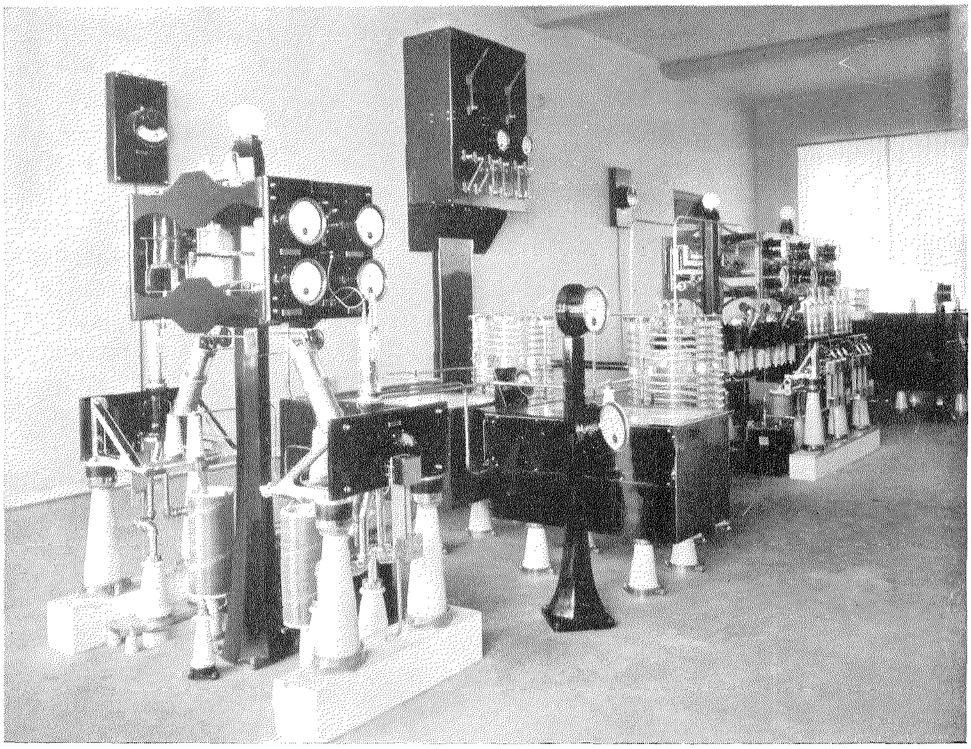


Figure 4—Power Amplifier from the Front, Looking Right.

should have a low impedance. All the anodes are therefore supplied through filter circuits which are terminated with a large value of smoothing capacity to prevent remodulation in the anode circuit at the lower frequencies, and consequent distortion.

Precautions have been taken to reduce carrier noise to the minimum possible value. The smoothing circuits of the plate and grid supplies have resonant frequencies well below the lowest modulation frequency, and very considerably lower than the lowest ripple frequencies delivered by the motor generator sets. The filament circuits are smoothed by audio frequency chokes and large banks of electrolytic condensers. Separate potentiometers are provided for the grid of each stage, and the output of each of these potentiometers passes through a separate smoothing circuit before going to the grid.

In order to obtain as nearly perfect reliability as possible, very adequate factors of safety have been allowed on the electrical specifications of the individual components. Large clearances have been left for all components under tension, and sizes have been kept on the liberal side in order to avoid the cramping which so often occurs, especially in the low power circuits of broadcasters. Tuning of all the low power circuits is accomplished by means of variable condensers, and the tappings on the coils are made by soldered connections brought out to screwed terminals. The final amplifiers are tuned by means of a short-circuited turn rotating inside each coil. Throughout the equipment all contacts are made either by soldered or by screwed connections; no clip contacts are employed. By these means the possibility of trouble due to bad and intermittent connections is reduced to a minimum.

The design almost naturally divides itself into two main parts, namely, the oscillator-modulator and the power amplifier. The power amplifier includes the radio frequency amplifiers Nos. 2 and 3, and the associated interstage and output circuits. The valves used in the power amplifier operate on a D.C. anode tension of 20,000 volts. It is exceedingly difficult to mount apparatus capable of withstanding this voltage in any form of enclosed framework. Attempts to do so generally result in mounting the apparatus as self supporting units with the framework serving as an enclosure only. The result is that very little is gained, and accessibility and simplicity of operation are invariably sacrificed. It may be thought that the appearance of the closed framework type of construction is better, since the apparatus is all enclosed and the surrounding framework can be well finished and fitted with front panels. However, it was considered that most of the apparatus for the power amplifier of such a large broadcaster would be of sensible dimensions, and consequently could be finished to present a pleasing appearance. It was realised that, from the point of view of manufacturing cost, this would undoubtedly result in a more expensive equipment. Nevertheless, the advantages from the point of view of simplicity of operation, accessibility and ease of maintenance, are so marked that it was decided to adopt the "open-type" construction for the power amplifier enclosure. The arrangement of the apparatus is clearly seen in Figures 4 and 5 which show the power amplifier with the enclosing frame removed.

The oscillator-modulator contains all the audio and radio frequency circuits up to a power sufficient to drive the power amplifier. In other words it is a complete broadcaster in itself, with a carrier output of 250 watts, and capable of 100 percent distortionless modulation. The apparatus contained in the oscillator-modulator is naturally of small dimensions, and operates on comparatively low voltages. Since it is low power apparatus, which should be screened from the power amplifier, all this equipment was centralised and built into a unit and completely enclosed.

Figure 6 shows the oscillator-modulator unit. It contains all the apparatus associated with:

(a) the generation of the radio frequency carrier wave at low power

(b) the amplification of the audio frequency currents

(c) the modulation of the radio frequency carrier wave by the audio frequency current—thus combining (a) and (b)

(d) the amplification of the modulated energy from (c) to the requisite power level for application to the grids of the power amplifier

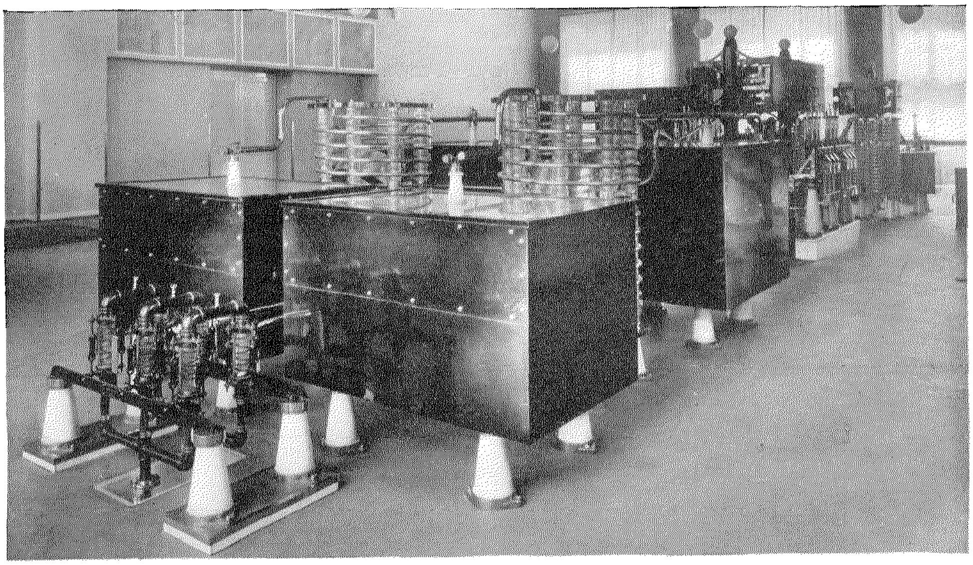


Figure 5—Power Amplifier from the Rear, Looking Left. The Artificial Antenna is on the Extreme Left.

The apparatus corresponding to each of these four divisions is built into a separate duralumin metal box (Figure 7) so as to be a self-contained unit, electrically screened from the other portions of the circuit. These boxes are referred to as:

(a) the master oscillator and coupling stage box
(b) the modulator and speech amplifier box
(c) the modulated amplifier box
(d) the first radio frequency amplifier box

As these boxes are located within the outer screening formed by the metallic enclosure of the unit, all of the apparatus, except the valves, is doubly shielded from the power amplifier stages. This complete screening, combined with the use of balanced push-pull circuits, ensures the complete suppression of undesirable regeneration or "feed-back." The boxes are mounted at the back of the slate panels forming the front of the unit; the meters and controls pass through holes in these panels. The valves are mounted outside on the back of the boxes, so as to be easily accessible for replacement. They can also be observed during operation through the perforated screens at the rear of the unit. Doors on the sides and rear of the boxes permit ready access to the apparatus inside.

Each of the boxes is mounted on slides and, in the event of any trouble, may be withdrawn bodily from the unit for inspection or replacement of any component. To withdraw a box, it is only necessary to undo the spring connections mounted on the side of the boxes and serving as conductors for the supply tensions. One marked advantage of this type of construction, is the circuit flexibility which results. If, at a later date, it is required to change or modify any particular circuit, it can be done without disturbing other circuits. For example, if it were desired to change the master oscillator and to employ one of a different type, or to derive the carrier frequency from a frequency transmitted from a distant point, then it would only be necessary to remove the box containing the present master oscillator, and to replace it with another box which would contain the new circuits. Similarly, changes can be made to any of the four boxes without interfering with the remainder of the equipment.

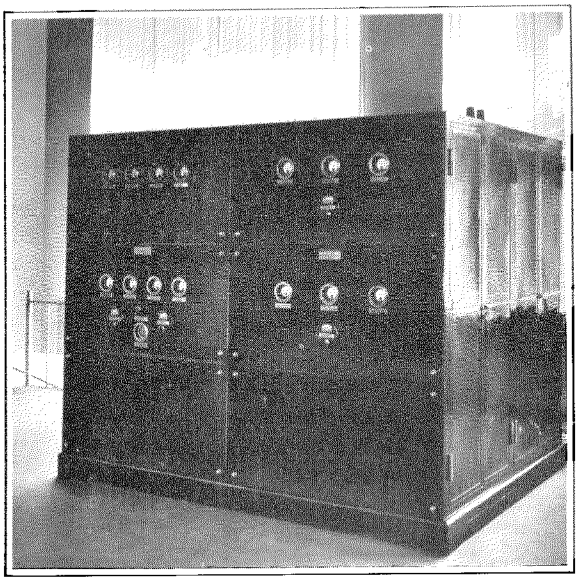


Figure 6—Oscillator-Modulator Unit.

Apparatus associated with the filtering and adjustment of the grid anode and filament power supplied to the various valves is not included in the boxes, but is mounted on panels accommodated on two racks standing at the right and left of the free space, which is entered through doors at the back of the unit. These panels include separate grid bias filter panels for each stage, filament rheostat panels for all the valves, a filament filter panel (employing dry electrolytic condensers of 10,000 microfarads capacity), a separate filter panel, for each anode supply, and so on. The apparatus on each panel is enclosed by a separate can cover, and jacks are provided to permit reading of the grid and filament voltage on each valve on meters provided at the top of the rack. A radio frequency peak voltmeter panel is also mounted on one of these racks. This arrangement of mounting the low frequency power circuits on separate racks, and having a separate panel for each filter circuit has great advantages from a maintenance standpoint as compared with the practice of assembling all the low frequency filter circuits together with the radio circuits in a single unit. With the latter system it is often difficult for an operator, in case of a fault, to trace out any particular circuit. With this arrangement, however, each filter and associated potentiometer or voltage dropping resistance is concentrated on one panel, in an easily accessible position, and has just one pair of wires leading into it and a second pair of wires leading away from it to the radio box concerned. It is therefore very easy, if trouble is suspected, to test the operation of the filter unit as a whole.

As it is obvious that the final characteristics of the equipment must in any case be inferior to the characteristics of the oscillator-modulator, this must be designed to possess the highest possible electrical performance. This performance may be conveniently examined from the point of view of circuit stability, frequency stability, linearity of modulation, frequency response curve and circuit flexibility.

As has been previously explained, in order to obtain perfect circuit stability, it was decided to adopt balanced push-pull circuits giving complete neutralization throughout the equipment. The whole equipment is screened, both between stages and from the power amplifier stages. By these means, an oscillator-modulator has been made which is absolutely stable and has no tendency towards spurious oscillation; the carrier frequency is therefore determined solely by the resonant frequency of the quartz crystal. This crystal oscillator consists of a one watt valve coupled by a radio frequency choke to the first coupling stage, which consists of a neutralised 50 watt valve acting as an amplifier and working into a tuned circuit. This in turn drives an amplifier consisting of two 50 watt valves in push-pull, working into a resistance potentiometer the output of which drives the grids of the modulated amplifier valves. This avoids all possibility of reaction at audio frequency due to the variation in grid current of the modulated amplifiers during modulation.

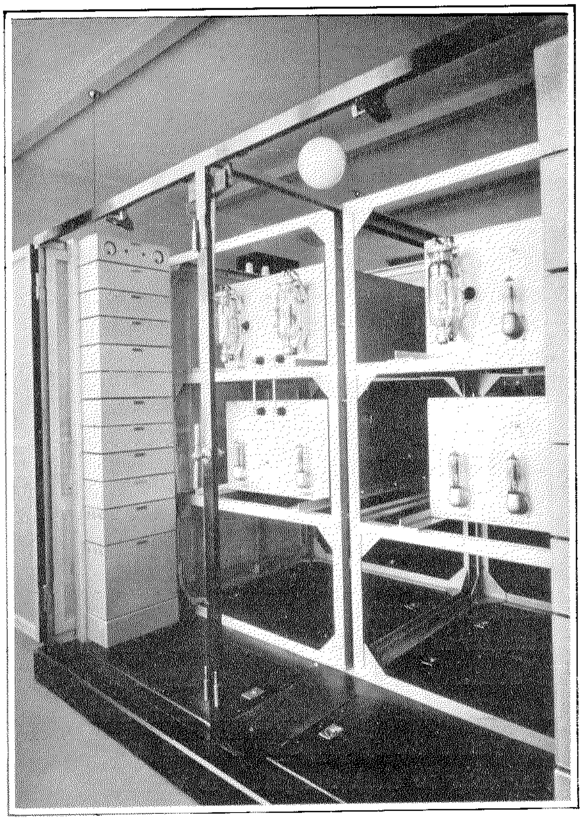


Figure 7—Oscillator-Modulator Unit—Rear View With Doors Open.

The audio frequency input transformer has a Permalloy core with an almost flat characteristic between the frequencies of 30 and 10,000 cycles. To preserve the same frequency response curve through the modulator unit, two high quality speech amplifiers drive the valve which modulates the modulated amplifier, the system used being a modification of the "Heising" system. Each of the two speech amplifiers uses a 50 watt valve. The modulator valve is a 500 watt valve operating on 5,000 volts. The modulated amplifier uses two 50 watt valves in a balanced push-pull circuit. These valves work normally when unmodulated with an anode tension of 750 volts. In order, therefore, to obtain 100 percent linear modulation, it is necessary to vary this anode tension from zero voltage up to 1,500 volts at audio frequency. This audio frequency voltage variation is supplied by the modulator valve, which must therefore be capable of delivering a voltage swing of 1,500 volts into the load represented by the modulated amplifier without departing from the linear portion of its own characteristic. To meet these requirements a valve working on a plate tension of 5,000 volts is used for the modulator. As the output of the modulated amplifier is increased by 50 percent when it is modulated 100 percent, this increase of power can only be derived from the modulator valve. In this equipment the power taken by the modulated amplifier valves is approximately 80 watts; the power to be delivered by the modulator is therefore 40 watts. The actual valve employed is capable of delivering an undistorted audio frequency output of very considerably more than 40 watts. Therefore, from both the voltage and power considerations, the modulator circuits are completely adequate to give the required 100 percent linear modulation.

When considered from the point of view of the load of the modulator valve, the output circuit of the modulated amplifier acts as a circuit in parallel with the effective impedance of the modulated amplifier valve itself. It is obvious, therefore, that as the output circuit is fed through a condenser, and itself consists of a capacity and inductance in parallel, the impedance of this shunt circuit will vary with frequency, and will decrease very much at high frequencies. This will affect the impedance into which the modulator valve is working, and will result in a loss at the higher frequencies. The anode stopping condenser is therefore replaced by a series resonant circuit consisting of a capacity and inductance in series, having a very small value of capacity, and tuned to the transmitting wavelength. This circuit has an almost zero impedance at the radio frequency, thus permitting the highest possible efficiency for the modulated amplifier. Owing to its small capacity it also presents a very high impedance to all audio frequencies, and thus permits the modulator valve to work into a constant impedance.

Radio frequency amplifier No. 1 consists of two 500 watt valves operated in a balanced push-pull circuit, and working on a D.C. anode potential of 5,000 volts. Every precaution has been taken to make this equipment as safe as possible for the operators, and naturally no components carrying tension are mounted on the front panels. The oscillator-modulator is surrounded completely by an enclosure; access to the interior is gained through a number of doors, each of which is fitted with electrical contacts which automatically remove all dangerous voltage when any door is opened. In order to provide against a possible failure of the automatic circuit it is necessary, before any door can be opened, to turn a handle fitted on the back of the equipment. Turning this handle removes the mechanical interlock from the doors, without which the doors cannot be opened, and at the same time operates a switch which first directly opens the supply circuits, and then puts a short-circuit on the condensers inside the unit. The operator is therefore prevented not only from touching any dangerous voltages but also from receiving a shock from the discharges of a condenser.

The middle panel on the left of Figure 6 is the master-oscillator and coupling stage panel. The two control dials are for the master-oscillator and the amplifier. Above the master-oscillator is the modulator and speech amplifier panel. The middle panel on the right is the modulated amplifier. The top panel on the right is the first radio frequency amplifier.

The power amplifier is driven by the oscillator-modulator through a short transmission line, and its function is to amplify the output from the oscillator-modulator unit to the level required for delivery to the antenna system. It includes all the water-cooled valves and their associated apparatus. Two stages of power amplification are necessary to increase the level required for feeding the antenna. Fourteen water-cooled valves are used, each capable of delivering a peak power of 40 kw. at 20,000 volts. The stage I power amplifier (or radio frequency amplifier No. 2) has two valves arranged in a balanced push-pull circuit and the stage II power amplifier (or radio frequency amplifier No. 3) has twelve valves arranged in a balanced push-pull circuit. Stage II power amplifier receives its drive from stage I through the medium of the interstage circuit.

In radio frequency amplifier No. 2, each valve is provided with separate meters indicating the anode current and grid current, and there is an additional meter indicating the total anode current of the two valves. Each valve is, of course, provided with a separate high frequency choke and D.C. stopping condenser, and also with a separate overload relay which opens the circuit breaker should the anode current become excessive. These relays are fitted with counters which indicate the number of times the valve has operated the circuit breaker, so that the behaviour of each valve throughout its life can be recorded, and any valve tending to be unreliable in service can be eliminated. A filament voltmeter is provided to show the filament voltage actually delivered to the filament of each valve. The meters, filament rheostats and similar apparatus are assembled on a small panel carried on a pillar so that the panel is visible over the top of the enclosure. To indicate the radio frequency drive applied to the grids of the amplifier

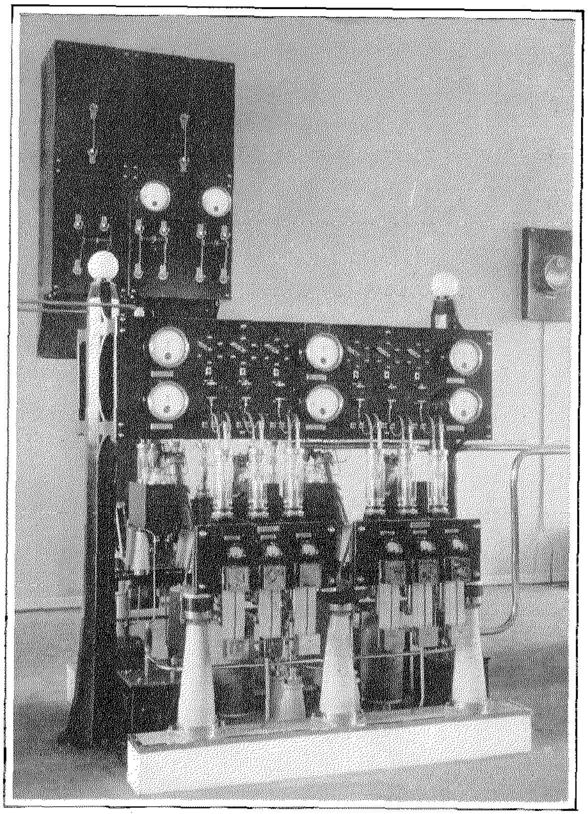


Figure 8—Radio Frequency Amplifier No. 3.

valves, a radio frequency peak voltmeter is built into the unit, the input being permanently connected across the grid circuit while the output is led away to a meter on the meter panel described above and to a second meter on the monitoring desk. The radio frequency amplifier No. 2 and the interstage circuit can be seen in Figure 4. The interstage tuned circuit which couples radio frequency amplifier No. 2 to radio frequency amplifier No. 3 is designed to meet both the output impedance requirements of radio frequency amplifier No. 2 and the input requirements of radio frequency amplifier No. 3. The coils consist of Pyrex formers on which are wound silver-plated copper tube. A short circuited turn rotates inside each coil. These short-circuited turns are coupled together and are operated by one turning handle.

Radio frequency amplifier No. 3 has six valves on each side of the push-pull circuit, and is assembled as shown in Figure 8. It is capable of delivering without overloading a maximum peak power of 480 kw. corresponding to 100 percent modulation of a carrier power of 120 kw. The valves in this stage are divided into two groups of six valves each, each group comprising in effect a separate push-pull amplifier having three valves on each side of the push-pull circuit. Suitable switching arrangements are provided in this stage to enable the station to be worked at half power using one group (six valves) or at full power using both groups (twelve valves). These switching arrangements provide for the necessary changes in the impedance of the input and output circuits in order to meet the impedance requirements of the power amplifier when using either six or twelve valves. The change from half to full power or vice versa can be accomplished in less than five minutes. As in the case of radio frequency amplifier No. 2, each valve is provided with a separate anode current meter and an indicating overload relay. Meters are also provided to indicate the total anode current of each group of six valves. Four grid current meters indicate the grid currents of each three valves and a filament voltmeter gives readings of the voltage across the filament of each individual valve. A radio frequency peak voltmeter gives a permanent indication of the radio frequency drive applied to the grids of this stage.

The assembly of the apparatus of radio frequency amplifier No. 3 is similar to that of radio frequency amplifier No. 2, except that the instrument board, on account of its length, is supported by a pillar at each end. One of these pillars is surmounted by an orange warning light which indicates that the radio frequency drive is applied to the unit. The other is surmounted by a red warning light which shows when the high tension voltage is on.

The output circuit is designed for transmission line feed to the antenna. Radio frequency amplifier No. 3 works into a tuned output circuit which is capacitatively coupled to the transmission line. The output circuit is designed to operate at the correct value of impedance required for a straight dynamic characteristic of the valves in radio frequency amplifier No. 3. The use of capacitative coupling reduces the harmonic radiation to a negligible value, as compared with inductive coupling, while retaining a very good bandwidth characteristic. Thermoammeters indicating the radio frequency currents in the various portions of the output circuit are mounted so that they can be seen over the top of the enclosure. For monitoring the output of the radio transmitter there is provided high tension peak voltmeter equipment which indicates the radio frequency voltage across the output circuit. The output from this equipment operates a meter directly connected therewith, as well as a second instrument on the monitoring desk.

Although the open type construction has been adopted for the power amplifier, the utmost protection has been provided for the operating personnel. The complete radio frequency amplifier equipment is surrounded by an enclosing railing about five feet high. This railing is of glass construction so that the apparatus can be seen through the enclosure. This enclosure surrounds the equipment on all sides so that it is possible to walk completely round the radio frequency amplifiers. Entry to the enclosure is by a gate controlled by a handwheel, and so arranged that it cannot be opened until the handwheel has been operated. The first movement of the handwheel operates the electrical safety system by opening the holding circuits of the contactors controlling the input to the main high tension transformer. It also opens the grid circuit. Further movement of the handwheel opens by mechanical coupling, the isolating switches which are located on the wall behind the radio frequency enclosure (in the view of the operator but out of his reach). These isolator switches break the grid and high tension connections of the apparatus in the enclosure and also short-circuit all the 20,000 volt circuits as well as the grid condenser. Finally, the handwheel unlocks the gate.

To enable the transmitter to be tested and adjusted without causing interference, an artificial antenna is provided. This permits accurate determination of the power output of the transmitter, which is a feature of great importance in tuning up the equipment. The artificial antenna, seen on the extreme left of Figure 5, is a non-radiating resistance in which the output of the transmitter can be dissipated instead of being delivered to the radiating antenna. The resistance is capable of dissipating some 200 kw. corresponding to the maximum output of the transmitter with full modulation. The resistance elements are water cooled, and meters are provided to indicate the rate of flow of the cooling water and the temperature rise, thus permitting easy determination of the power dissipated. This artificial antenna resistance is connected in series in the output circuit, and is adjusted to have a resistance value approximately equal to the value of the "equivalent series resistance" of the output circuit. Thus, with the same input to the radio frequency amplifier No. 3, and the same setting of components in the output current, the value of circulating current should be the same with the real antenna and the artificial antenna. It is possible to measure the power in the artificial antenna by two methods. First, knowing the resistance of the artificial antenna by reading the circulating current; second, by measuring the water flow and the temperature rise through the artificial antenna. The latter is a very accurate method of checking the power.

The monitoring desk (Figure 9) is the position at which the operator normally sits to supervise the functioning of the transmitter when it has been put "on the air." In form, it consists of a desk with a flat writing top and drawers at each side. On the top and at the rear of the writing portion is a sloping instrument panel on which are mounted various meters and switches. The meters are divided into two groups, one to the right and one to the left of the operator, the centre portion of the panel being taken up with the keys and switches. The meters in the left-hand group indicate various low frequency voltages and currents, while those in the right-hand group indicate radio frequency voltages and currents. There are four meters in the left-hand group. Two of these indicate the voltage of the 15,000 volt, three phase 50 cycle incoming supply, and of the 20,000 volts D.C. anode supply, respectively. The other two meters are associated with the audio frequency currents in the equipment. The first of these is intended to be connected in series with a similar meter on the line amplifier equipment and indicates the amplitude of the audio frequency voltages delivered to the input terminals of the radio transmitter. The other meter is in series with the modulator grid current meter on the oscillator-modulator unit, and indicates the grid current of the modulator

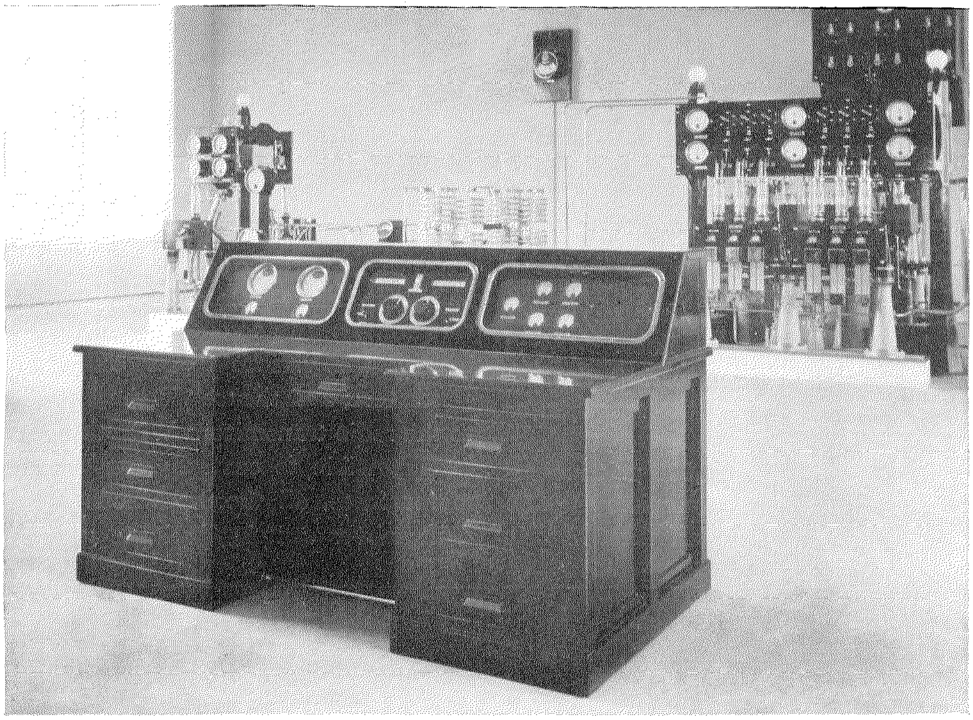


Figure 9—Monitoring Desk.

valve. This meter should, of course, normally read zero, as the occurrence of grid current on the modulator valve marks the overloading of the transmitter. It may therefore be regarded as an over-modulation indicator for the equipment. There are six meters in the right-hand group. Three of these indicate the value of the radio frequency peak voltages applied to the grids of radio frequency amplifier Nos. 2 and 3, and to the output circuit respectively. The remaining three meters are direct current milliammeters working in conjunction with remote thermo-elements; they indicate the radio frequency currents in each leg of the antenna transmission line and in the antenna respectively.

On the centre portion of the instrument panel are mounted a push-button for shutting down the transmitter in case of emergency, two knobs and two keys. One of the knobs operates a four point dial switch controlling the input of a built-in monitoring amplifier unit, enabling it to be connected with the incoming line, or with the output of any of the monitoring rectifiers connected respectively at the inputs of radio frequency amplifiers No. 2 and 3 or the output circuit. Thus the speech or music can be followed through the various stages of the transmitter, and the quality compared at each point. The second knob controls the gain of the monitoring amplifier. One of the keys switches the monitoring connections either to a loud-speaker or to a headset, while the other key switches the output of the monitoring amplifier either to the loud-speaker or the oscillograph, thus enabling either visual or aural monitoring to be employed. The left-hand portion of the desk top is made to slide back to disclose a cathode ray oscillograph equipment mounted on a panel sunk below the shelf. This oscillograph panel is equipped with all the necessary controls, phasing condensers, etc., for observing and measuring the modulation of the transmitter.

The Power Plant

The power for the operation of the broadcasting equipment is obtained from a 15,000 volt, three phase 50 cycle high tension line. This power is brought into the building by underground cable terminating at a 15,000 volt incoming supply switchboard. There are actually three separate high tension lines feeding three separate underground cables which are all brought into the station building. Facilities are available in the station building for switching the three lines and so accepting the supply of power from any one of the three lines. There is therefore no danger of any serious interruption in the service due to failure of the main power supply.

Power Supply System. The 15,000 volt incoming supply board (Figure 10), energises the 380 volt machine supply transformer, the 380 volt lighting transformer and the 20,000 volt rectifier transformer. From the 380 volt machine supply transformer the 380 volt three phase 50 cycle supply is taken to a distributing board where it is fed through a contactor and fuses to the motor generator sets, the water pumps and the mercury arc auxiliaries. This contactor, therefore, is the main 380 volt control. The feeders for the machines are each led to the change-over boards (each machine being supplied in duplicate) where they are each led through a contactor to the machines. The outputs of all the generators are taken to a contactor rack, on which are located the various feeder contactors for the generators, and thence via the filter circuit rack to the radio transmitter. With this system it has been possible to centralise respectively all the motor fuses, all the motor contactors, all the change-over switches, all the generator feeder

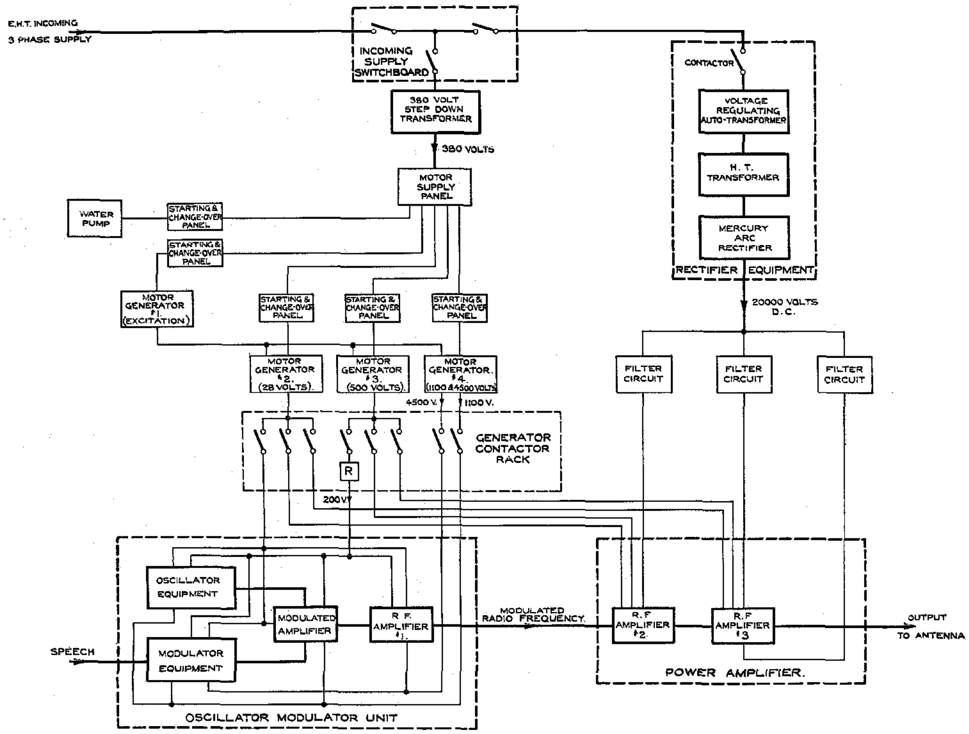

E.H.T. INCOMING
3 PHASE SUPPLY
INCOMING SUPPLY SWITCHBOARD
380 VOLT STEP DOWN TRANSFORMER
380 VOLTS
MOTOR SUPPLY PANEL
WATER PUMP
STARTING & CHANGE-OVER PANEL
STARTING & CHANGE-OVER PANEL
MOTOR GENERATOR #1. (EXCITATION)
STARTING & CHANGE-OVER PANEL
STARTING & CHANGE-OVER PANEL
STARTING & CHANGE-OVER PANEL
MOTOR GENERATOR #2. (28 VOLTS).
MOTOR GENERATOR #3. (500 VOLTS).
MOTOR GENERATOR. #4. (1100 & 4500 VOLTS)
4500 V.
1100 V.
GENERATOR CONTACTOR RACK
R
200 V
CONTACTOR
VOLTAGE REGULATING AUTO-TRANSFORMER
H. T. TRANSFORMER
MERCURY ARC RECTIFIER
RECTIFIER EQUIPMENT
20000 VOLTS D.C.
FILTER CIRCUIT
FILTER CIRCUIT
FILTER CIRCUIT
OSCILLATOR EQUIPMENT
MODULATED AMPLIFIER
R. F. AMPLIFIER #1.
SPEECH
MODULATOR EQUIPMENT
OSCILLATOR MODULATOR UNIT
MODULATED RADIO FREQUENCY
R.F AMPLIFIER #2.
R.F AMPLIFIER #3
OUTPUT TO ANTENNA
POWER AMPLIFIER.

Figure 10—System Schematic of Radio Transmitter.

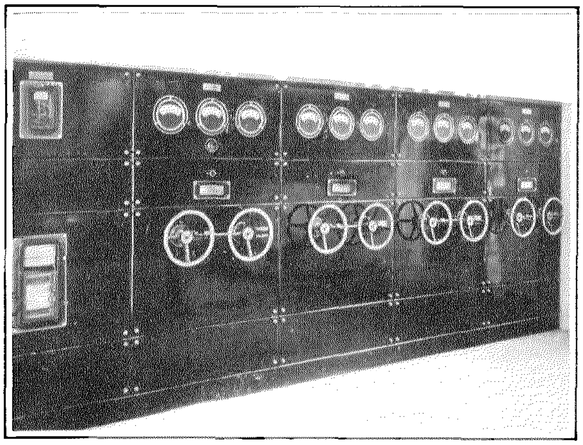


Figure 11—15,000 Volt Incoming Supply Panel.

contactors, and all the filter circuits. Further, this centralisation has been done in such a way that it is possible in a few seconds to follow any circuit through from the 380 volt main contactor to the exit from the filter circuit. From the operational standpoint this is a great asset. The feeder for the 20,000 volt transformer goes to the auto-transformer (for the tapping switch) and then through a contactor to the 15,000 volt primary. The secondary feeds the mercury arc rectifier direct.

Incoming Supply Switchboard. Figure 11 shows a front view of the 15,000 volt incoming supply switchboard. Here the main incoming supply power is metered, controlled, and distributed to the transformers. This board functions as the main position for applying or disconnecting the power from the station as a whole, and is not associated with the normal starting and stopping or adjustment of the radio transmitter. It contains the hand-operated main switchgear and main overload breakers, which are closed when the station is put into operation. No further operation of this switchboard is necessary during the running of the radio transmitter. The board also contains a number of instruments which give useful information regarding the incoming power supply, as for example, line voltmeters, line ammeters, frequency meters, watt meters, and kilowatt-hour meters. The switchboard is constructed on the cubicle system, the high tension apparatus, such as oil-break disconnect switches and air-break isolating switches, being located in a cubicle, the front of which is formed of enamelled steel panels carrying the meters and handwheels for operating the switches. There are five such cubicles, the front panels of the five lining up in front to form one continuous power board.

Each panel, except the first, carries two handwheels, one of which operates the oil-break switch within the cubicle, while the other operates an air-break isolating switch mounted above the cubicle and out of reach when the latter is entered. The two handwheels are interlocked to prevent opening of the air-break switch until the oil switch is open. The handwheel operating the air-break isolating switch retains a special key which, when released, permits access to the cubicle by means of a door at the rear. In this way perfect security of the operating personnel is assured, while by the use of a different key for each cubicle it is possible to enter any cubicle without rendering the other cubicles inactive. A lamp on each front panel indicates when the corresponding oil switch is closed.

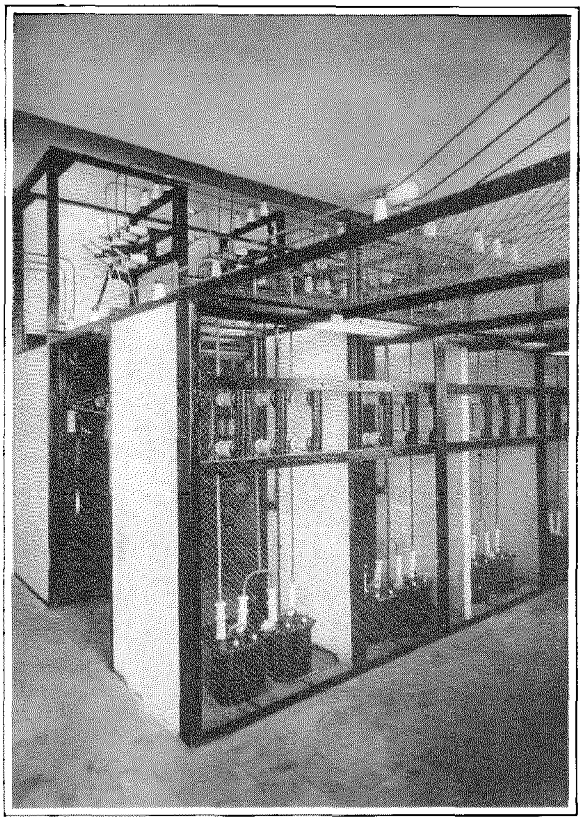


Figure 12—15,000 Volt Incoming Supply Panel—Rear View.

At the rear of the cubicles is another set of cubicles containing the instrument transformers, etc., as shown in Figure 12. These transformers are also completely enclosed by expanded metal screens. Between the instrument transformer cubicles and the main cubicles, there is a passageway giving access for inspection, etc. To obtain access to the instrument transformer cubicles, however, it is necessary to obtain the key from the isolating handwheel located on the front panel associated with the instrument transformer. Behind the instrument cubicles are the 380 volt transformer vaults. These vaults contain three 15,000/380 volt step-down transformers, one for the machines, one for the lighting, etc., of the building, and one as a spare for the other two transformers. With this system of expanded metal screens and passages, it is possible to view all the equipment with absolute safety for the personnel.

The five cubicles of the incoming supply board, proceeding from left to right of Figure 11 are: the incoming voltage feeder cubicle, the main control cubicle, the lighting control cubicle, the 380 volt control panel, and the high tension rectifier control panel.

These panels are provided with a kilowatt-hour meter, frequency meter, voltmeter, ammeter and power factor meter for the total supply. Wattmeters and ammeters are provided on the 380 volt panel, the lighting panel and the high tension rectifier panel.

The 380 Volt Distribution Panel takes the 380 volts from the machine transformer and distributes it to the various circuits. It contains all the fuses necessary for each circuit, and also houses the main 380 volt contactor which closes the supply from the secondary of the 15,000/380 volt transformer. It is so arranged that the opening of the front panel gives access to all the fuses. This front panel is, of course, fitted with an automatic switch which cuts off the 380 volt supply from the panel, so that it is safe for the operator.

Motor Generator Sets. Four motor generator sets supply the filament current and the grid bias to all the valves used in the equipment, and the anode current to the valves used in the oscillator-modulator unit. The motors of these sets receive their power from the 380 volt distribution panel. From this panel the power is led to the four change-over panels, on each of which is a contactor which applies the power to the motor. These contactors are controlled by a push-button on the transmitter control switchboard, and an auxiliary contact on the first contactor energising the second contactor, which in turn operates the third, and so on, so that all the machines are started one after the other by pressing a single button. Centrifugal starters are incorporated on the various motors, so that these are started automatically when the appropriate contactor is closed. As already mentioned, the motor generators are installed in duplicate, and on each change-over panel are the necessary switches for changing-over the motor and the generator respectively, and also the fuses for each generator. The outputs of the generators are led via the generator contactor rack and the filter circuits to the various circuits concerned. These contactors are operated by push-buttons on the transmitter control switchboard. Motor Generator Set No. 1 is a two unit machine comprising a three phase 380 volt induction motor and a 110 volt 12 ampere direct current generator. This machine supplies current for excitation of the remainder of the generators used in the equipment. Motor Generator Set No. 2 is a two unit machine comprising a three phase 380 volt induction motor and a 28 volt 1,100 ampere direct current generator. This machine supples filament current for all the valves in the equipment. An automatic D.C. voltage regulator associated with this generator keeps the output voltage constant within ±1 percent. Motor Generator Set No. 3 is a two unit machine comprising a three phase 380 volt induction motor and an 800 volt 10 ampere direct current generator. This machine supplies grid bias for all the valves in the equipment, the voltage being broken down to the values required for the individual valves by means of potentiometers. Motor Generator Set No. 4 is a four unit machine comprising a three phase 380 volt induction motor, a 1,100 volt, 1 ampere direct current generator, and two 2,500 volt double commutator direct current generators. These two generators are connected in series to deliver 0.75 ampere at 5,000 volts. The 1,100 volt generator supplies anode current for the 50 watt air cooled valves used in the oscillator-modulator, and the two 2,500 volt generators supply anode current for the 500 watt air cooled valves used in the same unit. All the generators have been specially built to give as small a voltage ripple as possible, so as to simplify the filter circuits and obtain noiseless carrier. The four change-over boards are located between the machines which they control. They are provided with doors at the back, through which access is obtained to the equipment. This door is, of course, provided with a mechanical switch which breaks the 380 volt supply to the board, and so enables the operator to work with safety.

High Tension Anode Power Supply System. This system is capable of supplying a power of approximately 500 kw. at a D.C. voltage of 20,000 to the anodes of the valves in the radio frequency amplifiers Nos. 2 and 3. The equipment may be considered to comprise a high voltage rectifier, a contactor and voltage regulating equipment, and filter circuits. In view of the large power consumption involved, it was extremely important to employ a system having the highest possible electrical efficiency. Therefore, a mercury arc rectifier was used. The actual overall efficiency of the equipment, as measured from the high voltage incoming feeder to the output of the rectifier (including the power consumed by the rectifier auxiliaries) in 93 percent. A Hewitt type twelve-phase rectifier is used with glass rectifier bulbs enclosed in oil filled tanks. The rectifier system comprises in effect two identical but separate twelve phase rectifier equipments each delivering 250 kw. at 10,000 volts; the outputs are connected in series to give 500 kw. at 20,000 volts, so that, should one rectifier suffer a serious breakdown, it is possible to operate with voltages up to 12,000 volts with the remaining rectifier. Under these conditions, it would still be possible to obtain something like 50 kw. in the antenna. Thus something approximating duplication of the rectifier equipment is obtained.

The two H.T. transformers are of the self-cooling, oil-filled type, and are identical. Each has a three-phase primary winding and a twelve-phase secondary, the latter consisting of four separate three-phase star windings so arranged that the voltages in the stars are successively displaced by a quarter of a period. The primaries of the transformers are operated from the 15,000 volt three-phase 50 cycle supply and each of the three-phase secondary windings has a voltage of 2,500 volts from phase to neutral. As, however, the secondary windings are, from a D.C. standpoint, connected in series, each is insulated for a working of 24,000 volts. The neutral point of each secondary star (except the first which forms the negative output terminal of the unit) is connected to the cathode of a rectifier bulb, the ends of the three-phase windings being connected to the three anodes of the following bulb. Each rectifier bulb is a three-phase unit, having three anodes, and delivers a rectified voltage of 2,500. The outputs of four bulbs are connected in series to give a D.C. voltage of 10,000 volts with a twelve-phase ripple. The bulbs are mounted in oil filled steel tanks; since each tank contains two bulbs it is in effect a 5,000 volt unit. Two of these tanks are associated with each transformer and are also connected in series, so that one transformer with two tanks comprises a complete 10,000 volt rectifier system. Two of these 10,000 volt rectifier units (i.e. two E.H.T. transformers and four tanks) make the complete 20,000 volt rectifier equipment. One tank complete with two bulbs is mounted as a spare, so that it can immediately be switched into service in place of the faulty tank, leaving the latter to be opened and the bulb replaced when opportunity permits. It is exceptional for a rectifier bulb to fail in service. In general, a failing bulb refuses to excite (especially after several hours rest) or excites in an irregular fashion, so that indication is given to the operator when he is starting up the equipment that one of the bulbs needs to be changed. The starting arrangement incorporated causes the arcs to be struck almost instantaneously and without the need of any mechanical manipulations, thus enabling the high tension voltage to be applied by push-button control, with the same degree of facility as in the case of a rectifier employing thermionic valves. Lamps on the outside of the tanks indicate that the arcs are functioning properly.

Contactor and Voltage Regulating Equipment. The power supply to the rectifier equipment is taken through the high voltage contactor which is connected between the output from the incoming supply switchboard and the primary of the high tension transformer. This contactor, which is located in the H.T. rectifier enclosure, is operated by a push-button on the transmitter control board, and is the means of applying or removing the 20,000 volt supply from the power amplifier. The voltage regulating equipment permits the value of the D.C. voltage delivered by the rectifier to be adjusted over wide limits. It comprises a tapped auto-transformer which is connected before the primary of the H.T. transformer, thus controlling the voltage applied to the latter. The tappings on the auto-transformer are brought out to a tapping switch, which can be operated on load, and which gives a range of adjustment of ±20 percent in 2 percent steps. The tapping switch is controlled from the transmitter control switchboard, thus enabling the D.C. anode voltages to be regulated from the radio room. The control is actually made by means of a small electric motor which is coupled to the shaft of the tapping switch. This motor can be run in either direction by means of a system of automatic contactors which are controlled from the radio room by means of two push-buttons. An arrangement is provided which automatically stops the motor when the tapping switch has arrived at either of its two extreme positions. In addition to this fine control, provision is made for changing the D.C. voltage in large steps for operating; for example, on reduced power when tuning or testing or making changes in the radio transmitter. This adjustment is, of course, not continuous, but gives certain definite steps of voltage. As previously stated, the rectifier consists of four 5,000 volt rectifier tanks connected in series, and high tension isolator switches are provided to enable the output from one, two, three, or four tanks to be used, as desired, thus giving nominal voltages of 5,000, 10,000, 15,000 and 20,000 volts. Three inductance coils are connected in the primary of the rectifier transformers to limit the short circuit current of the rectifier. Access is obtained to this rectifier assembly through a door which is so arranged that it cannot be opened until the key has been released from the main disconnect switch of the high tension rectifier control panel of the 15,000 volt incoming supply board. Furthermore, this door is so arranged that when it opens, it automatically operates a switch which connects the high tension bus-bars to ground, and thus also discharges the smoothing condensers. Figure 13 shows the rectifier installation including tapping switch and contactor.

Filter Circuits. Three separate filter circuits are provided: one for radio frequency amplifier No. 2 and one for each side of the push-pull circuit of radio frequency amplifier No. 3. The use of separate filters prevents coupling between the stages due to common impedance in the anode circuit. It also has the advantage that, by splitting up the smoothing capacity, the amount of stored energy that can be instantaneously delivered into a fault is considerably reduced. Each filter comprises an oil immersed choke and a smoothing condenser. The filter for radio frequency amplifier No. 2 has an inductance of 12 henries and a capacity of 5 microfarads. Each of the filters for radio frequency amplifier No. 3 has an inductance of 10 henries and a capacity of 15 microfarads. The condensers are designed for normal working at 25,000 volts D.C. The amount of ripple remaining in the 20,000 volt D.C. supply, after filtering, is reduced to less than 0.03 percent.

Transmitter Control Switchboard. Located in the radio room, the transmitter control switchboard is the control position from which all the normal switching operations and adjustments of voltages are carried out. The motor-generator sets and pumps are started up, and the 20,000 volts D.C. is applied to the power amplifier by push-buttons on this board. The voltages of all the generators and of the 20,000 volts D.C. supply are adjusted by handwheels at this position. Meters on the switchboard indicate the values of all supply voltages used. Apart, therefore, from radio frequency circuit tuning, which does not normally require to be repeated once the station has been put into service, the whole equipment is controlled, started, and stopped from this position. The maximum voltage on this control switchboard is 110 volts.

The transmitter control switchboard is built in the form of six separate panels, fronted with highly polished black enamelled slate, and lined up to form one continuous switchboard. Each panel mounts all of the controls and instruments corresponding to one particular supply. Large

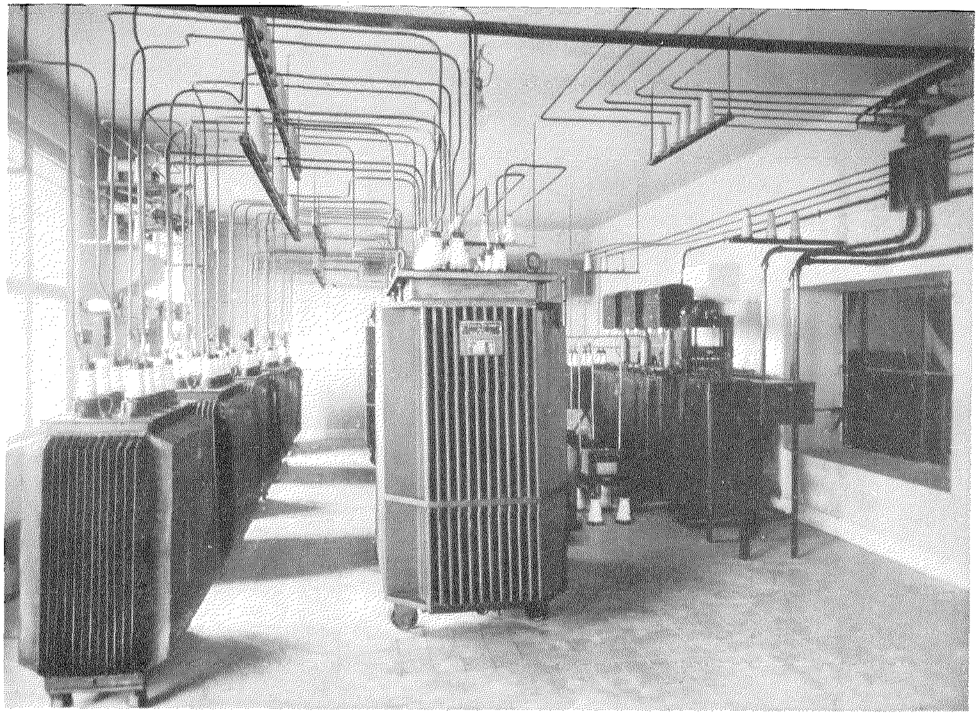


Figure 13—20,000 Volt Rectifier.

meters are supplied so that the operators can read them from any position in the room. Each of the slate front panels is divided into four sections. The upper section carries the meters, of which there are a voltmeter and ammeter for every supply voltage. The second section carries the push-button, above each of which is located a signal lamp which is lighted by an auxiliary contact on the associated contactor thus showing when the contactor is closed. The third section carries the voltage regulating control for the machines and the 20,000 volt rectifier, and also the overload and no volt relays. The lowest section is a blank panel. The six panels are arranged so that the transmitter is started up by successive operations, moving from the first panel to the sixth panel.

380 Volt Supply Panel. This panel controls the 380 volt supply from the step-down transformer, and puts into operation all the running machinery in the equipment, and a line ammeter. Four push-buttons are provided, the first of which closes the contactor connected between the 380 volt transformer and the 380 volt distribution panel, and puts the 380 volt supply on the bus-bars of the latter. The second push-button starts up all the motor-generator sets, while the third push-button starts up the water circulating pump. The last push-button on this panel starts up the auxiliaries in the high tension rectifier equipment, thus putting the latter in a condition to be placed on load.

Excitation Panel. The panel controls the auxiliary voltages utilised in the control system. There are two such voltages: one of 110 volts D.C., used solely for excitation of the various generators, and one of 110 volts A.C., used for operating all contactors and signal lamps. The first of these supplies is obtained from motor-generator No. 1 and the second from a small step-down transformer connected across the output of the 380 volt supply transformer. The excitation panel has two push-buttons. One operates a contactor closing the field circuit of the 110 volt generator, while the other operates a contactor which supplies the 110 volts A.C. to the bus-bars of the control circuit, thus rendering the latter operative.

Filament Generator Panel. This controls the 28-volt supply to the filaments of all valves in the radio equipment. Three push-buttons are provided for applying the 28-volt supply to the oscillator-modulator unit and to radio frequency amplifiers Nos. 2 and 3 respectively.

Grid Generator Panel. This panel controls the 800 volt supply from motor-generator No. 3, employed for providing negative bias for the grids of the valves. Three push-buttons operate contactors which apply grid voltages to the oscillator-modulator and the radio frequency amplifiers Nos. 2 and 3 respectively.

H. T. Generator Panel. This panel is associated with the control of motor-generator No. 4 supplying high tension current to the valves in the oscillator-modulator unit. There are two supplies to be controlled by this panel, the 1,100 volt supply and the 5,000 volt supply. Two push-buttons operate contactors connecting the generators with the oscillator-modulator unit.

20,000 Volt Supply Panel. This panel controls the supply of rectified high tension power for the power amplifiers. An "On-Off" push-button controls the application of this supply, by operating the contactor which applies the high voltage incoming supply to the primary of the rectifier transformer. Figure 14 shows the transmitter control switchboard.

Control Circuits. The control circuits are based on the fundamental principle that no voltage higher than 110 volts shall be led to the control switchboard. For this reason, the control circuits, including push-buttons, signal lamps and contactors are fed from a 110 volt three-phase A.C. supply obtained from a 380/110 volt transformer located behind the 380 volt distribution panel. Similarly, all the generators are excited from the 110 volt D.C. supply, which is reserved exclusively for this purpose. This has the advantage, so far as the 28 volt machine is concerned, of eliminating the uncertainty of "building up" which is not infrequently encountered in self-excited low voltage generators.

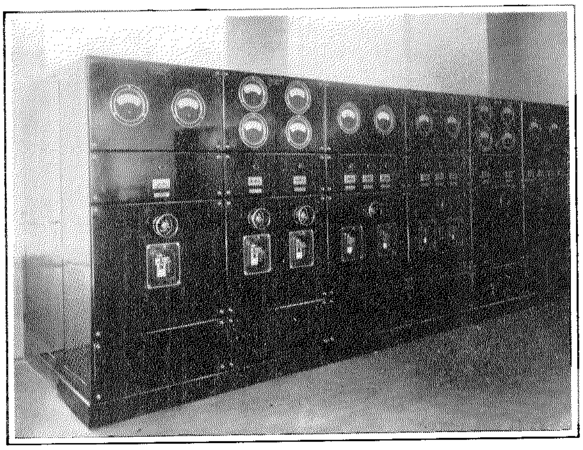


Figure 14—Transmitter Control Switchboard.

The 110 volt transformer is connected across one phase of the 380 volt incoming supply through a hand switch operated from the front of the 380 volt distribution panel; the transformer can thus be isolated so as to cut off the 110 volt A.C. supply entirely. This is, of course, not intended for use as a normal control, but permits work to be done on the control circuit without removing the whole 380 volt supply. The output from the 110 volt transformer divides into two portions, one portion going to the various motor starting contactors and other circuits controlled by the "starting" push-buttons on the 380 volt supply panel of the transmitter control board, while the other portion goes to a contactor which applies the 110 volts to a set of bus-bars on the generator contactor rack. This contactor is closed by the "control circuit" push-button on the transmitter control switchboard. The bus-bars energised by this contactor supply the generator contactors and other circuits of the security system. When this contactor is open the generator contactor rack is dead.

All the push-buttons are of the "momentary contact" type, returning to the unoperated position immediately after being depressed. The contactors which they control are locked up when operated, by means of auxiliary contacts, and are unlocked when once they are de-energised, either by operation of the security system or by depression of the "off" button. After the contactors have been opened, owing, for example, to a fault or the opening of one of the safety doors, it is impossible for the power to be re-applied in any manner except by pressing the appropriate "on" button.

The general principle of the security system is that each of the contactors applying power to the transmitter is energised by the 110 volt A.C. control circuit, and has in series with the operating coil the contacts of the security devices associated with that particular supply, so that in the event of the security device operating, the contactor is opened and the supply taken off. Furthermore, each security device is arranged only to take off the supply from those parts of the equipment which are affected by the fault with which it is associated. Thus, failure of the filament or grid bias supply de-energises the associated no-volt relays, which open the contactors applying anode voltage to all valves in the equipment. Failure of the water circulation operates the water flow security device, the contacts of which cause the opening of the rectifier contactor and the filament contactors for radio frequency amplifiers Nos. 2 and 3, thus taking anode voltage and filament current off all the water-cooled valves. Opening the door of the power amplifier and output circuit enclosure takes off the 20,000 volt supply and the grid bias supply from the radio frequency amplifiers. Opening the door of the oscillator-modulator unit removes the 1,100 volt and 5,000 volt supplies. The application of anode voltage to any unit before the corresponding grid and filament voltages are on is prevented by energising the high tension contactor through auxiliary contacts on the grid supply contactor for that unit, which in turn is controlled by auxiliary contacts on the corresponding filament contactor. In this way, damage to material or danger to personnel due to errors in operation or the occurrence of faults is absolutely prevented; at the same time difficulty and confusion resulting from unnecessarily removing the supplies from unaffected parts is avoided.

WATER COOLING SYSTEM

The water cooling system carries away the waste heat from the high power water-cooled valves, and is capable of dissipating some 400 kw. An explanatory schematic is shown in Figure 15. The circulating pump draws water from the expansion tank through a filter and forces it through the inlet hose coils to the various units of the power amplifier, returning through the outlet hose coils to the water cooler. Actually there are twelve separate hose coils, one coil for the inlet and outlet of each valve in radio frequency amplifier No. 2, and a separate coil for the inlet and outlet of each group of three valves in radio frequency amplifier No. 3. From the water cooler, the cooled water is returned to the expansion tank. Between the pump and the hose coils, the water passes through the water control board, where are mounted the various stopcocks, meters, and water security devices. The radio units are at the highest point of the water system, so that the pressure there is a minimum. Consequently, to change a valve, it is only necessary to stop the water pump. The water in the thermionic valves will run back into the expansion tank through the outlet pipe. The water is held in the inlet pipe by means of a non-return valve (see Figure 15). Each water cooled valve is mounted in a water jacket in which the water is distributed in a thin sheet over the anode, moving at high velocity and with a stream-line flow. This design has been found particularly effective in preventing the formation of bubbles on the anode.

Water Control Board. On this board are mounted the indicating and alarm thermometers connected in the water return leads from radio frequency amplifiers Nos. 2 and 3. A fourth thermometer indicates the inlet temperature of the water delivered to the units. In the event of the water temperature approaching the safety limit, these alarm thermometers cause a bell to ring and a lamp to light. On this board are also mounted water flow relays which remove the power from the units in the event of a failure of the water flow. These relays are placed in the outputs from the radio frequency amplifiers. Each relay is in the form of a water flow meter, which indicates the flow, and causes the circuit breaker to open if the flow falls below normal. The water flow indicator consists of a "U" tube working on the differential pressure produced by a Venturi tube. The "U" tube contains mercury on which floats a nickel-plated steel ball. Outside the tube, which is of non-magnetic material, is a movable permanent magnet whose poles follow the movement of the ball as the mercury changes its level due to change of pressure or water flow. On the magnet is fixed a needle to indicate the flow in litres per minute, and also a small contact maker which operates a relay and breaks the filament circuit when the water flow becomes too small for safe operation of the thermionic valves. In the event of the flow through any circuit failing, it is possible, therefore, to determine which of the units is giving trouble by observing these meters. In addition there is provided a master water flow meter which indicates the total water flow at any time. The control handwheels for the water supply to the various units are mounted on the water control board.

Figure 16 shows the six panels of the water control board. The first panel is fitted with a gauge indicating the pressure of the water pump and a milliammeter which shows current leakage through the hose coils of radio frequency amplifier No. 3. The pressure gauge is fitted with a

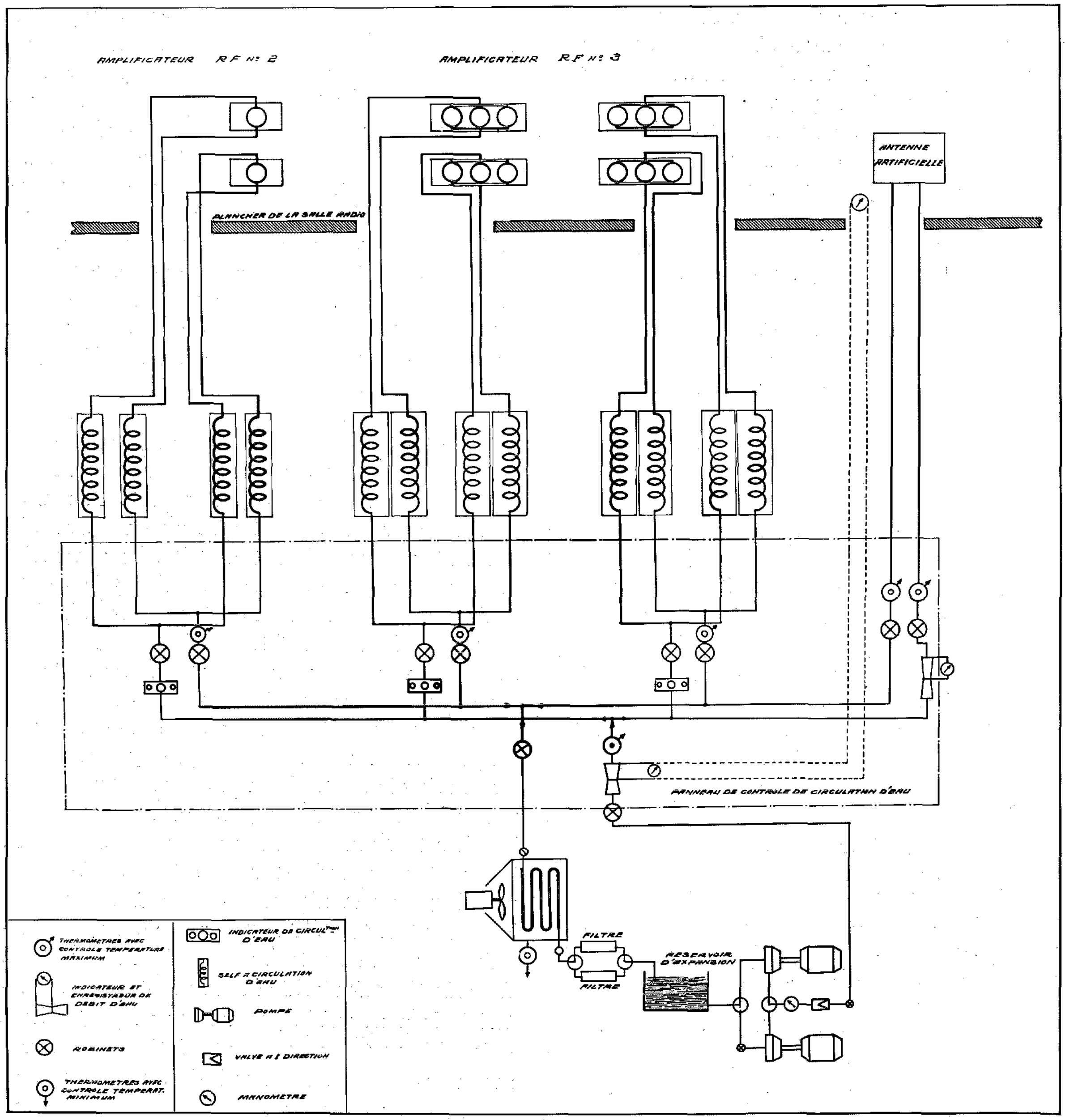

AMPLIFICATEUR R F N° 2
AMPLIFICATEUR R F N° 3
ANTENNE ARTIFICIELLE
PLANCHER DE LA SALLE RADIO
PANNEAU DE CONTRÔLE DE CIRCULATION D'EAU
FILTRE
FILTRE
RESERVOIR D'EXPANSION
THERMOMETRES AVEC CONTROLE TEMPERATURE MAXIMUM
INDICATEUR ET ENREGISTREUR DE DEBIT D'EAU
ROBINETS
THERMOMETRES AVEC CONTROLE TEMPERAT. MINIMUM
INDICATEUR DE CIRCULTION D'EAU
SELF A CIRCULATION D'EAU
POMPE
VALVE A 1 DIRECTION
MANOMETRE

Figure 15—Schematic of Water System.

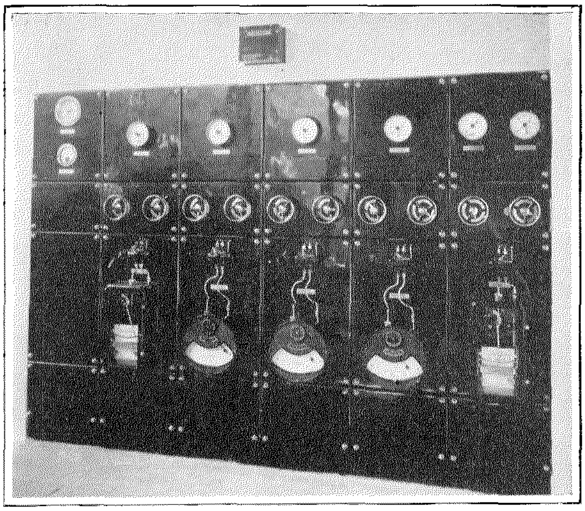


Figure 16—Water Control Board.

safety contact which causes a bell to ring in the machine room and the radio room when the pressure reaches too high a value. There is provided also a safety valve which lets out the water into a reservoir in the event of serious over pressure. On the second panel is mounted an inlet thermometer, a water flow register for recording on a paper drum, and two main control cocks, one in the inlet pipe and the other in the outlet pipe, so that the whole water system can be controlled from this panel. The third panel contains the apparatus for radio frequency amplifier No. 2, consisting of an outlet thermometer, two control cocks, and a water flow indicator. The fourth and fifth panels are for radio frequency amplifier No. 3, one panel for each set of six valves. They each contain the same apparatus as the third panel. The sixth panel is for the artificial antenna and consists of inlet and outlet thermometers with inlet and outlet control cocks and a water flow recorder. It is very easy, therefore, to measure the inlet and outlet temperatures and the water flow, so that the power which is dissipated in the artificial antenna can be arrived at instantaneously.

The Water Pumps. There is one working motor pump set and one spare. The centrifugal pump is capable of delivering 600 litres a minute against a head of 40 metres. There is one push-button (located on the transmitter control switchboard) in conjunction with an automatic starter for starting and stopping the motors of the pumps, the starter being connected to either motor as required by a change-over switch. The same push-button serves to start up the fans. Signal lamps on a control board near the pump room indicate which of the pumps and fans are running. The water circuit contains a non-return valve which keeps the system full of water after the pump has been shut down.

The Water Cooler. This consists of a large honeycomb radiator through which cold air is drawn from outside the building by two motor driven fans (Figure 17). The air is expelled either through the roof or through a system of pipes for heating the building, the flow being regulated by vanes in the flues. One spare fan set is provided. The two working fans are started up by a delay action contactor which functions after the pump has been started. The choice between the three fan sets is made by means of isolating switches near each fan set. There is a thermometer at the bottom of the radiator with a low temperature alarm contact, inasmuch as the winter temperatures near Prague are very low and the cooler might freeze when the station is not working.

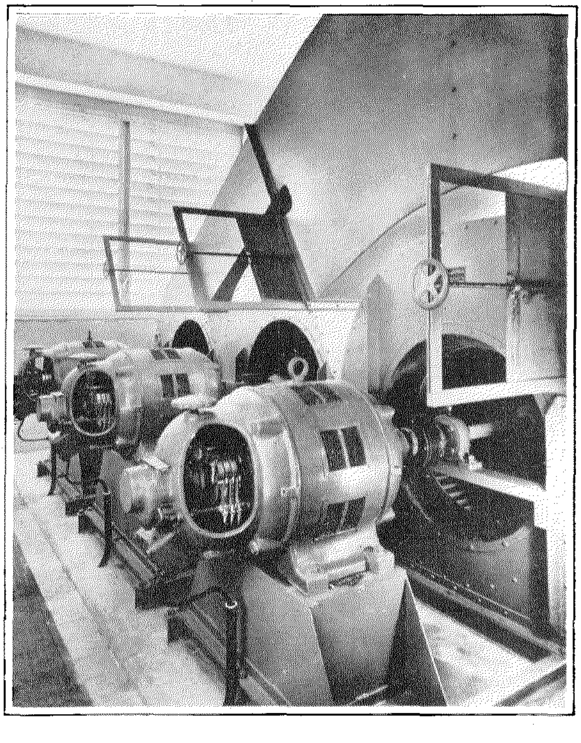


Figure 17—Motor Driven Fans for Air Blast Cooler.

The Reservoir and Filters. In order to even out the flow of water and to allow for slight evaporation, a copper reservoir of 2,500 litres capacity is provided in the hose-coil room, mounted slightly above the level of the pump. As it is essential that the water fed to the valve jackets should be as free from sediment as possible, two water filters are supplied—one in service and one spare. The hose coils and reservoir are housed in a room of which the water control board forms one wall. The door to this room has a safety switch for removing the high tension voltage should anyone try to enter during operation. In the neighbouring room are the pumps and cooler. The motor-driven fans suck air in through louvers in the outer wall of the building and blow it through the cooler. Brass piping is used throughout. The piping passes from the hose coils through the wall above the water control board, along the ceiling of the machine room (supported every five feet by insulated supports) and then through large porcelain bushes supported on glass plates in the ceiling directly under the radio units. The whole group of pipes is surrounded by an earthed metal screen. Short lengths of rubber piping are inserted between the brass pipe and the radio units in order to keep the radio frequency and direct currents from reaching the hose coils except in so far as they are carried by the water.

Antenna and Earth System

The fundamental requirement for the antenna was a strong radiation in a horizontal direction, which necessitates a high antenna. Consequently the towers are 492 feet high, insulated, and self-supported. They are spaced 820 feet apart. The antenna has been designed for transmission line feed, the transmission line terminating in the antenna hut in which is located all the necessary apparatus for feeding and tuning the antenna.

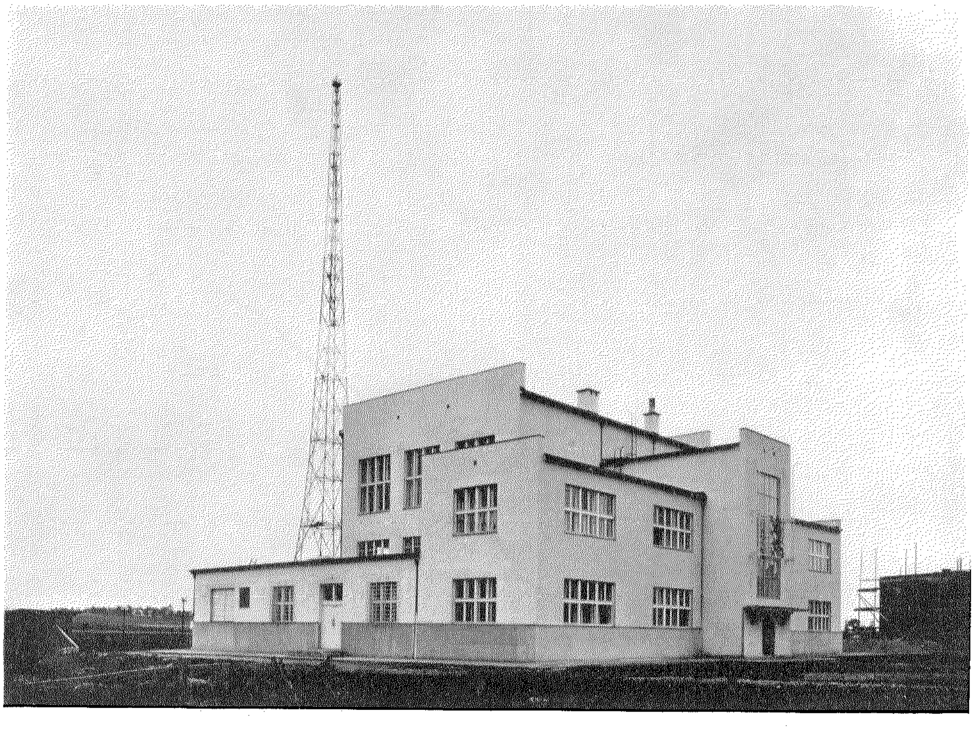


Figure 18—Exterior of Radio Transmitter Building.

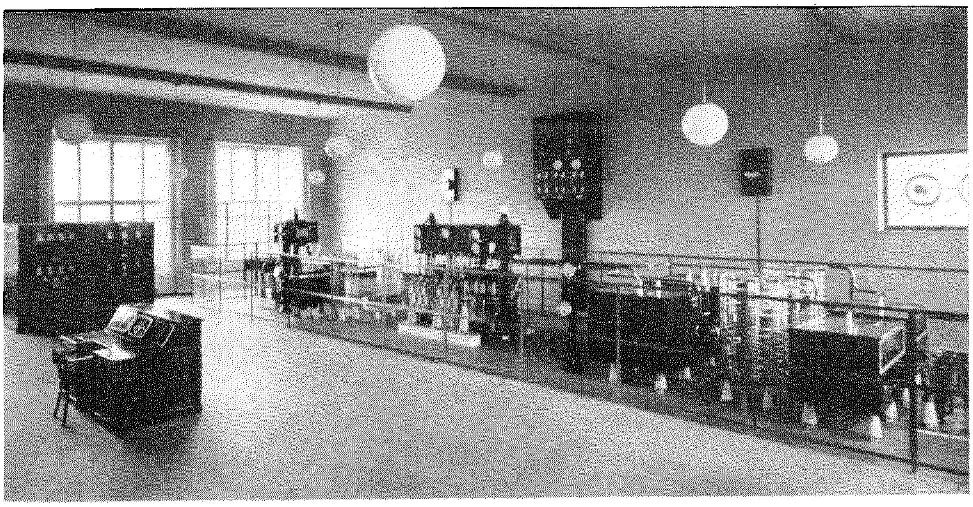


Figure 19—Radio Unit Enclosure.

Radio Transmitter Building

The radio transmitter is housed in a two story building of very modern architecture (Figure 18). All the radio equipment is located on the upper floor and all the power equipment on the ground floor. The cabling between the two floors is arranged on cable boards so that every cable can be traced individually throughout its entire length. Figure 19 shows the arrangement of the first floor. There is one main room in which is located the radio transmitter proper (i.e., the oscillator-modulator, and the power amplifier), the monitoring desk, and the transmitter control switchboard; there is also a studio, a control room, a valve store room, a writing room, and engineer's and assistant engineer's offices. The studio is only for emergency use—the main studio, of course, being in Prague. In the control room the incoming telephone lines are terminated on the line amplifier equipment.

The building has a copper roof which is connected by copper bus-bars running down all four walls to the ground. There is also a copper mesh screen in the floor of the radio room so that all the radio apparatus is contained within a copper screen.

The ground floor also has one large room exactly under the radio room, namely, the machine room. Surrounding the machine room on three of the sides are built low wings. The fourth side has offices, etc., which are located immediately under the offices on the upper floor. Figure 20 shows the layout of the ground floor. By arranging apparatus in the wings it has been possible to have all the switchboard controls, etc., located in one room, namely, the machine room. In the right hand wing are the 20,000 volt rectifier equipment and the 20,000 volt filter equipment, separated by an expanded metal corridor. This corridor permits the operators to see the rectifier and filter apparatus while it is under tension, without any danger. In the rear wing are located on the right, the 15,000 volt incoming supply switchboard, in the centre the 380 volt distribution board with the contactor and filter racks behind, and on the left the water control board with the hose coils behind. In the left wing are the water pump and water cooler rooms. In this wing there is also a switching station which controls the three 15,000 volt incoming lines. This equipment is not part of the broadcasting equipment but is actually a high tension switching station which has been located in the transmitter building in view of its appropriate geographical situation. The re-

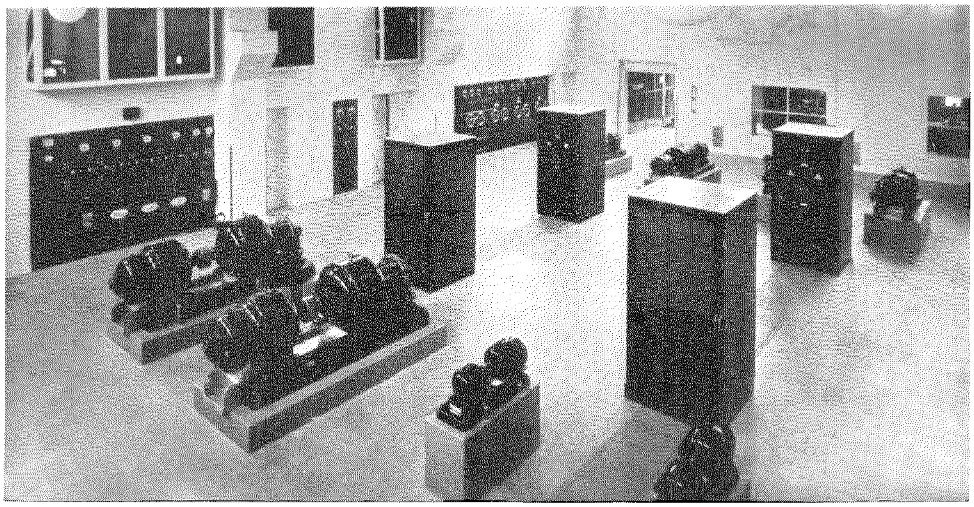


Figure 20—Machine Room.

maining rooms on the ground floor are the store rooms, the battery room, and the workshop.

The building follows the most modern practice not only as regards the general architecture of the fabric but also in the interior decoration and fittings. The main impression given in the interior of the building is the extremely high degree of natural lighting, brought about by the large number of windows, and greatly assisted by appropriate interior decoration.

The basement of the building contains a heating plant for the warm air heating system. This plant works in conjunction with the heated air which is discharged from the air blast cooler when the broadcaster is working. The hot air is circulated through the building by means of ducts built into the walls.

The equipment layout adopted gives the utmost simplicity of operation and ease of maintenance. It may be considered as consisting of the radio, control, and power equipment. Obviously, the control should be in the same room as the radio equipment, so that facilities are given to the operators for full control of all power as well as radio equipment. The power equipment, however, should preferably be located in another room or rooms, and should not have any controls which need to be operated during normal running.

To start the complete broadcasting equipment the first operation is to close the switches on the 15,000 volt incoming supply board. When these switches have been closed the primaries of the 380 volt machine and lighting transformers and the 20,000 volt autotransformer (for the tapping switch) are all closed. Next the control cocks on the water control board are opened. This completes the operations on the ground floor (in the machine room) and no further operation is necessary on this floor until the complete station is closed down. All further adjusting and controlling is done at the transmitter control board in the radio room. After the complete equipment is in operation full indication of the performance of the station is given to the operator at the monitoring desk.

Lining Up Broadcasting Circuits

By E. K. SANDEMAN

International Telephone and Telegraph Laboratories, Inc.

THE increased use of land lines for connecting up broadcasting stations and the advances in the requirements which broadcasting services impose on such land lines have introduced many new problems, one of which is a need for a rapid means of measuring line equivalents accurately and quickly. At their last plenary session, the C.C.I. decided on a method of measuring such equivalents and adjusting the levels, generally known as lining up, which seemed to be eminently suitable. Broadly this method consists in adjusting the transmission equivalent so that the voltage measured across the line at all frequencies in the range effectively transmitted is constant at a number of chosen points along the line. It is extremely simple in that it permits the use of automatic measurement of circuit equivalent; furthermore, suitable level measuring apparatus bridged across the line at each of the chosen points indicates immediately without additional adjustment whether the speech or music traversing the circuit at any moment is at the correct level.

In practice when the constant voltage method is adopted in order to ensure that measured equivalents shall add together to give a substantially true overall equivalent, the output impedances of all amplifiers must be reduced by an amount which results in lowering the effective power handling capacity of all output stage vacuum tubes. The reason for this will be explained later.

The C.C.I. recommendations regarding permissible deviations in overall equivalents have recently been tightened and it is now specified that the difference between the values of transmission equivalent measured at any two frequencies in the range of frequencies effectively transmitted shall not exceed 4.3 db (0.5 néper). Hence, there appears to be a demand for a precision method of lining up circuits which is universal in that it will not impose any special requirements on circuit components and therefore will permit the full power handling capacity of the amplifier to be realised.

A method of lining up circuits is discussed below which meets the above demand and has substantially all the advantages of the constant voltage method; this method is entirely consistent with present practice and fundamental principles of transmission and has the special advantage that each repeater section is made distortionless quite independently of any external link other than the impedance of the transmitting repeater which may have any value and is readily standardised. This is of special importance at switching points where a number of lines of different impedance may converge. In what follows the new method will first be outlined, and the constant voltage method will then be described in detail along with a brief discussion showing the special circuit means which the constant voltage method makes necessary.

Definitions

Before taking up the special points involved it will simplify the discussion if the meanings of a few of the terms used are described explicitly.

Constant voltage is any a.c. voltage, varying in frequency over any required range of frequencies, which has the same value at all frequencies.

Constant e.m.f. is any a.c. e.m.f. varying in frequency over any required range of frequencies, which has the same value at all frequencies.

Constant power is any power contained in a single frequency varying over any required range of frequencies which has the same value at all frequencies.

A distortionless amplifier is one in which the input and output impedances are resistances of zero angle and which reproduces constant voltage applied *across* its input terminals as constant e.m.f. *in* its output circuit. (This does not give rise to constant voltage across its output circuit unless the impedance into which the amplifier operates is infinity or a resistance of zero angle.)

It may be helpful here to emphasise the difference between voltage and e.m.f. When a voltage

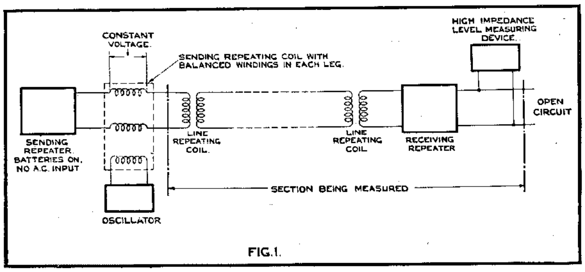

CONSTANT VOLTAGE.
SENDING REPEATING COIL WITH BALANCED WINDINGS IN EACH LEG.
HIGH IMPEDANCE LEVEL MEASURING DEVICE.
OPEN CIRCUIT
SENDING REPEATER. BATTERIES ON. NO A.C. INPUT
LINE REPEATING COIL.
LINE REPEATING COIL
RECEIVING REPEATER
SECTION BEING MEASURED
OSCILLATOR

FIG. 1.

v is applied between the grid and filament of a vacuum tube a voltage appears *across* any external circuit into which the output of the valve works

$$V = \mu v \frac{Z}{Z + R_0}$$

where Z is the impedance of the external circuit.

R_0 is the internal impedance of the vacuum tube and μ is the amplification factor of the vacuum tube. The quantity μ v is the e.m.f. in the output circuit of the tube, and when Z is made equal to infinity, V, the external voltage measured across the output terminal, is equal to the e.m.f. = μ v. It is of course a well known fact that the open circuit voltage of any generator is equal to the internal e.m.f. In the present standard transmission measuring sets a constant voltage is applied to the line in series with a resistance representing the internal impedance of the apparatus to be connected to the line. In this way the voltage across the line varies with frequency in the same way as it does in practice for constant e.m.f. in the sending amplifier. In what follows, therefore, this method of applying constant voltage to the line has been called the constant e.m.f. method.

Criterion of a distortionless land line system.

Since all broadcasting lines operate between amplifiers any land line system can only be regarded as distortionless if when connected between distortionless amplifiers constant power entering the transmitting amplifier causes the receiving amplifier to deliver constant power to a zero angle resistance connected to its output.

Constant power in the input of the distortionless transmitting amplifier means constant volts across its input and so constant e.m.f. in its output circuit.

Similarly constant power delivered by the receiving amplifier into a pure resistance load postulates constant volts across its input.

Hence a land line system is distortionless if constant e.m.f. generated in a pure resistance (equal to the output impedance of the distortionless amplifier which is used for transmitting) bridged across the sending end of the system produces constant voltage across a resistance bridged across the receiving end of the system, this resistance being equal to the input impedance of the distortionless receiving amplifier.

Proposed Method of Lining Up Broadcasting Circuits

1. Studio lines. Constant e.m.f. is sent from the studio (constant voltage in series with an impedance equal to the output impedance of the studio sending amplifier) and the circuit is equalised so that the open circuit voltage measured at the output of the first repeater (i.e., the e.m.f. in the output of the first repeater) is constant.

2. Repeater sections. Constant e.m.f. is sent from each repeater station (constant voltage in series with an impedance equal to the output impedance of the repeater) and the circuit is equalised so that the e.m.f. in the output of the next repeater is constant.

3. Transmitting station lines. Constant e.m.f. is sent from the last repeater station and the circuit is equalised so that constant voltage is produced across an impedance bridged across the receiving end of the circuit equal to the input impedance of the receiving amplifier.

It follows that constant e.m.f. in the output of the studio sending amplifier gives rise to constant e.m.f. in the output of every repeater and to constant voltage across the input of the receiving amplifier at the radio transmitter.

Figure 1 shows the proposed method of sending and receiving constant e.m.f. applied to a repeater section, the output of a repeater being used to give the necessary sending impedance.

From the point of view of ease of measurement there is no difference between the procedure proposed here and the procedure recommended by the C.C.I. For programme control, volume indicating means can be bridged across the repeater output in the same way as is done in the case of circuits lined up on a constant voltage basis. In practice this would undoubtedly prove entirely satisfactory but it is open to the academic objection that the quality of the speech or music applied as a voltage to the measuring gear differs from the true quality by an amount equal to the difference between the e.m.f. in the output of the amplifier and the output voltage across the terminal of the amplifier when connected to the line, both expressed as a function of frequency. This difference is not negligible from the point of view of equalisation with steady frequencies but on speech or music it would be difficult and probably impossible to detect by a level measurement integrated over the frequency range. Level measuring apparatus may, however, be bridged across the output of an interstage branching amplifier specially provided for the purpose.

C. C. I. Recommendations

1. Studio Lines and transmitting station lines.

In answer to Question 23 (i) the following recommendations appear:

"La ligne reliant le studio à l'origine du circuit téléphonique à grande distance doit être établie de façon qu'une tension appliquée à l'origine de cette ligne et constante à toutes fréquences, engendre une tension également constante à l'origine du circuit utilisé pour les transmissions radiophoniques; de même, la ligne reliant le dernier répéteur à la station émettrice doit être établie de manière que, dans les mêmes conditions, la tension mesurée aux bornes d'une résistance de 600 ohms, substituée à la station émettrice, conserve, quelle que soit la fréquence, une valeur constante."

2. Repeater sections.

"La 3ème Commission de Rapporteurs propose, en outre, à l'Assemblée Plénière de Paris 1931, de recommander aux Administrations et Compagnies Exploitantes d'organiser les réseaux de radio-diffusion et de régler les répéteurs placés sur les circuits de ces réseaux de manière que, lors de l'application d'une tension V à l'entrée d'une section de ligne quelconque, on obtienne la même tension V a l'entrée de toutes les sections suivantes pour toute la bande des fréquences effectivement transmises, quelle que soit l'impédance des différentes sections de ligne."

From the above it is seen that the C.C.I. propose to line up circuits so that constant voltage at the input to the studio line produces constant voltage across the input to the receiving amplifier (assuming this to be 600 ohms in impedance).

This is not a condition for overall distortionless transmission unless constant voltage at the transmitting end and constant e.m.f. at the transmitting end are identical or in constant ratio at all frequencies. Owing to the large variation with frequency in the impedance of nonloaded cables, such as normally constitute studio lines, if established methods of impedance matching were adhered to, constant e.m.f. would give rise to voltages applied to the line differing several decibels within the range of frequencies effectively transmitted. These differences correspond to distortion in the overall system which is nowhere taken care of.

An obvious means of overcoming this difficulty is to drop the impedance of the transmitting amplifier to such a low value that the voltage applied to the line approximates sufficiently closely to the e.m.f.; in this case it makes no difference whether the circuit is lined up on a constant voltage or on a constant e.m.f. basis. In order to get a sufficiently close approximation it is necessary to drop the impedance to less than half the lowest impedance reached by the line in which case it becomes necessary to increase the power handling capacity of the vacuum tube.

A similar difficulty occurring at branching points can be overcome by the same means. The C.C.I. proposes to equalise circuits so that constant voltage applied to the input of a line results in constant voltage appearing at the output of the receiving repeater with the outgoing line connected. Where a branching repeater is used with a number of separate outputs working into lines of different impedance it is evidently not possible to make constant voltage at the transmitting end produce constant voltage in the output of every branching repeater without recourse to individual equalisation in each branching repeater. It is of course a simple matter with a single equaliser to make each repeater deliver constant e.m.f. Again, therefore, we are driven to low output impedances and tubes of higher power handling capacity.

While it may be the case that at any given stage in evolution the tube power handling capacity economically available may exceed requirements, there are many obvious ways in which that extra power handling capacity may be useful in the future, for instance in enabling smaller conductors to be used or in raising the general level of the system and reducing noise.

It is submitted that any method of lining up circuits which inherently demands a higher power handling capacity from the amplifiers than is warranted by the required circuit levels is wasteful.

Pneumatic Ticket Distributing Systems for Toll Boards

By CARL BECKMAN

Mix and Genest A. G., Berlin

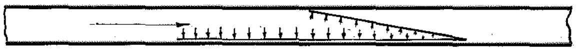


Figure 1

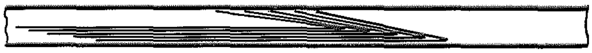


Figure 2

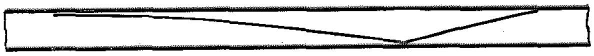


Figure 3

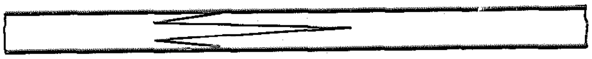


Figure 4

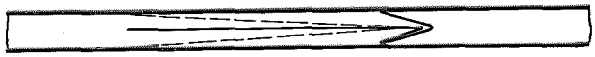


Figure 5

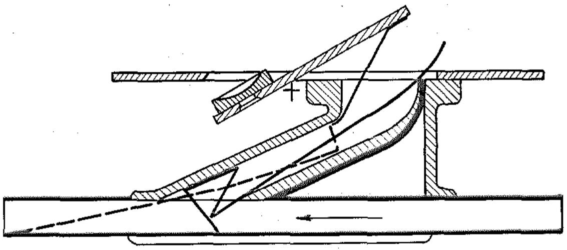


Figure 6

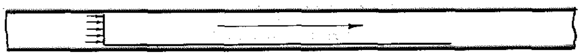


Figure 7

TOLL exchange engineers charged with the care of certain types of pneumatic tube systems for the distribution of toll tickets know what troubles can arise with such plants and what a large amount of work is required to keep installations in proper working condition. Among the prominent causes of troubles and losses are "jams" which are caused by stoppages of the tickets while in transit in the tubes and which occur particularly while traffic is heaviest. Many attempts were made to overcome this difficulty and finally Mix and Genest A. G., after years spent in studying the improvement and development of ticket distributing systems, successfully solved the problem. They found jams in the tubes were caused primarily by the method employed in folding the tickets. They found also that operation could be much improved by changes in the valves and in the cross sectional contour of the tubes.

This paper outlines the study made of the factors involved and the changes that were finally successfully adopted.

Folding of Tickets

A widely used method of ticket folding is shown in Figure 1. According to this method the ticket is first bent at a position marked by a line and then is introduced into the tube with the bent flap head on. The result is that the driving air acting upon the ticket presses it against the inside wall of the tube, thus increasing friction. It will be apparent that with this method of folding the ticket, the danger of jams in the tubes is relatively great, particularly during times of heavy traffic, since the tickets tend to wedge into each other, thus further increasing the friction of the tickets against the tubes to such a degree that entire stoppage finally results (Figure 2). In such cases it has often been found necessary to cut the jammed tube section or burn out the tickets within the tube with resultant loss of the message records. It should be noted that static electricity, due to the friction of the tickets pressed against the inner walls of the tube, also causes the tickets to stick tightly to the wall, especially when the air in the tubes is very dry. As a result the flap

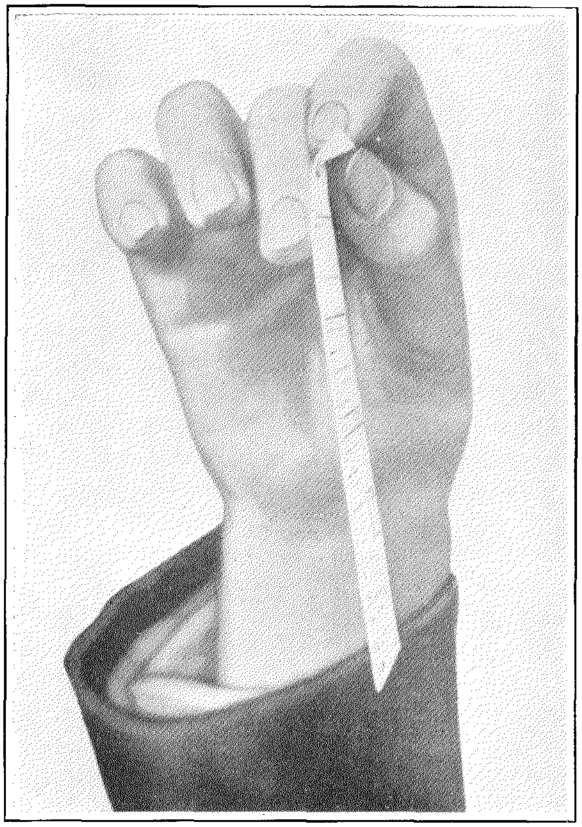


Figure 8

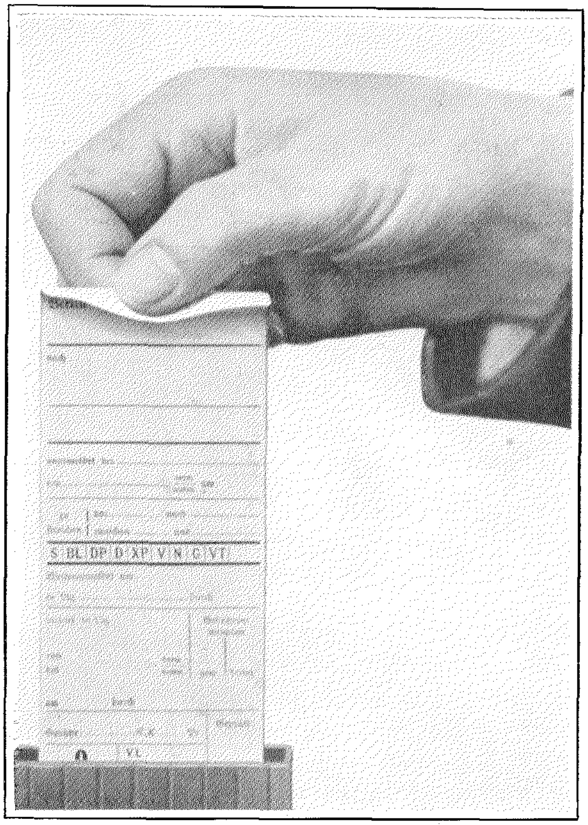


Figure 9

of the ticket often becomes opened enroute (Figure 3) and the ticket is stopped. To release the tickets, toll ticket officials use so-called "drivers," as indicated in Figure 4, but their use is objectionable inasmuch as they frequently cause further stoppage.

Another well-known method of folding tickets is indicated in Figure 5. According to it the ticket is first folded similar to the method indicated in Figure 1 after which another fold is made so that the head of the ticket becomes arrow shaped. The advantage of this double folding is that the ticket occupies the cross sectional area of the tube almost completely and rubs against the walls of the tube at the edges only with consequent reduction of jams due to static electricity. On the other hand, the double folding of the ticket causes increase of friction. Another drawback inherent in this method is that the edge of the flap is easily opened especially when the ticket is introduced in a vacuum transmitting valve (Figure 6). In this case on opening the flap of the transmitting valve, the air enters the sending slot and is of course greater the nearer the transmitting valve is located to the receiving apparatus. Under these conditions when the front edge of the ticket is leaving the sending slot the entering air tends to open the fold of the ticket. This happens invariably if the operator holds the ticket a moment so that it is kept from starting at once. With this method also, stoppages in the tubes cannot be absolutely avoided particularly during hours of heavy toll traffic, when the tickets press against each other and against the inner walls of the tube. The fact that with this method of folding the front end of the ticket has four thicknesses of normal paper, makes this tendency more pronounced.

For more than eight years Mix and Genest have employed an improved method of ticket folding (Figure 7) which has practically eliminated all the above mentioned drawbacks. When printing the ticket a dotted line is impressed at a distance of eight millimeters from one end and

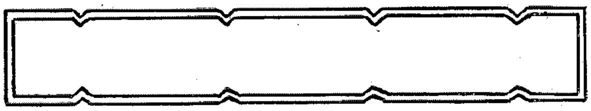


Figure 10

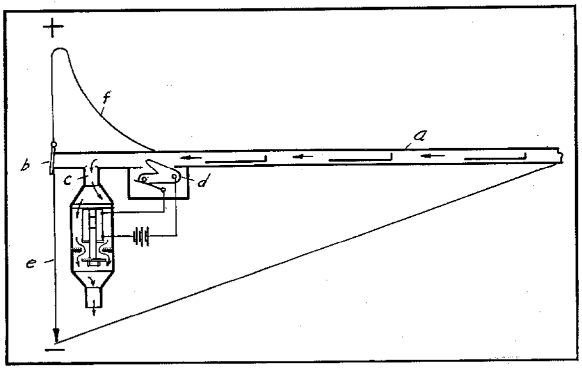


Figure 11

the ticket is folded at this point without any special appliance by pressing the ticket between the thumb and the forefinger as indicated in Figure 8. Figure 9 indicates the manner of inserting the ticket into the transmitting tube. The ticket travels in the tube with the folded flap in the rear and at right angles to the main portion of the ticket. Since the flap of the ticket almost fully occupies the sectional area of the tube, it of course acts as the driver of the ticket. Thus the air pressure is no longer divided into several components and the frictional resistance is not increased by pressure of the ticket against the inner wall of the tube. Moreover, with this method the air pressure is fully utilized for the conveyance of the ticket since it practically floats in the air stream, scarcely touching the tube walls.

In addition to the advantages derived from folding, improvement has been effected in the Mix and Genest transmitting tubes by fitting them with longitudinal inside ribs (Figure 10) and thus further minimizing frictional resistance. With longitudinal ribbed tubes the tickets merely touch the inner surfaces of the tubes along a few lines. With these tubes and the improved method of ticket folding the power consumption of the pneumatic ticket distributing systems is reduced by 30% or 40%. In other words a considerably reduced air pressure is adequate for driving the tickets.

Vacuum Receiving Valves

Vacuum receiving valves formerly used, for example, the motor driven valves, as well as the automatic ejection valves, give considerable operating trouble. Mix and Genest have introduced an entirely new type of vacuum receiving valve for pneumatic ticket distributing systems by the use of which reliable ejection of the tickets is assured.

The general design of this valve is illustrated in Figure 11. The transmitting tube "a" terminates in the flap "b," the air pipe "c" leading to the blower being connected to the transmitting tube close to the receiving flap. An electrically controlled valve inside the tube serves to stop the air current passing through the tube. The magnet of the electrically operated valve functions by means of contact "d" over a relay chain, not shown in the drawing.

The air pressure in the tube is shown diagrammatically. The height "e" representing the low pressure decreases towards the open end of the tube and finally reaches the zero point. When a ticket touches contact "d" the vacuum in the valve is cut off but the air in the tube continues to move along the tube and generates high pressure towards the end as indicated in the curve "f." Thus the exterior high pressure on the valve is compensated for, the flap opens and the ticket is ejected without coming to rest in the receiving valve. It will be evident, therefore, that the efficiency of the Mix and Genest device is by far greater than that of the formerly used ejection apparatus.

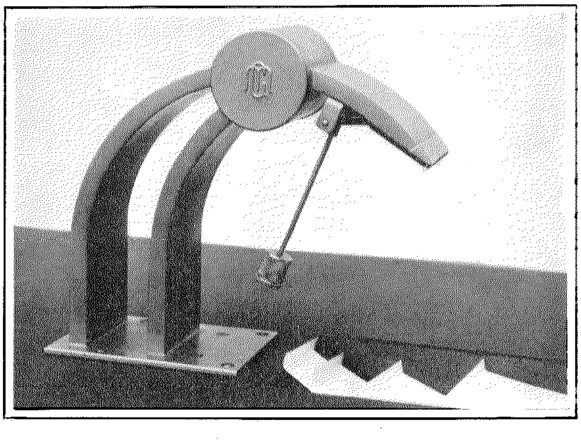


Figure 12

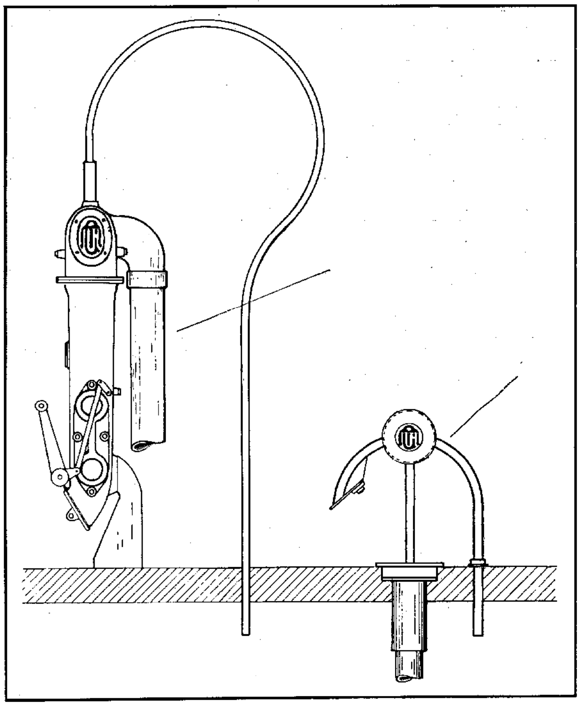


Figure 13

Stoppages in the receiving valve shown in Figure 12 are thus practically eliminated, and can only occur in case the electric control device should fail to operate. In case stoppages should occur, they are recognized by the buzzing sound emanating from the ticket in the tube, and are at once eliminated by a series of compressed air impulses following each other at intervals. The vacuum receiving valve used formerly is shown for comparison with the new valve in Figure 13. When it is required to install several valves, as is necessary in large installations, it is recommended that the ejected tickets be conveyed by a moving belt to a common receiving position. This may be done in a very simple way by arranging the receiving valves at an acute angle to the moving belt. Thus the tickets are piled up consecutively at the end of the belt and may be taken away according to the order of their arrival. The arrangement is shown in Figure 14.

Results Achieved

Experience under actual service conditions has shown that with tickets with the improved folding, stoppages have been entirely eliminated even during periods of heavy traffic. As soon as the bent end of the ticket is introduced into the sending slot of the vacuum transmitting valve (Figure 6) the ticket is started on its way without difficulty by the entering air. The tickets follow each other through the tube in the manner indicated in Figure 15. Fifteen or twenty tickets may be dispatched immediately after one another or they may be transmitted in small parcels of six or eight. Incidentally, in the Mix and Genest method the ticket is folded at an unimportant point near the end so that with this exception the ticket remains entirely smooth, an advantage of great importance in view of the value of the records contained on the tickets.

The following toll exchanges have adopted the Mix and Genest method of ticket folding with results satisfactory to all concerned:

TOLL EXCHANGE

IN		SINCE	
Plauen i. V.	Germany	1925	
Duesseldorf		1924	
Koblenz		1927	
Bielefeld		1927	
Oslo	Norway	1924	
St. Gallen	Switzerland	1930	
Geneva		1930	
Turin	Italy	1931	(re-designed for M. & G. folding method)
Rome		1931	(re-designed for M. & G. folding method)
Genoa			(being built)
Olten	Switzerland		(being built)

Other toll exchanges previously employing older methods of ticket folding are now adopting the Mix and Genest method. While there is a

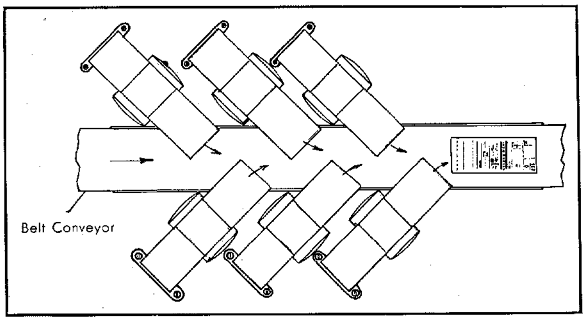


Figure 14

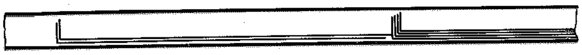
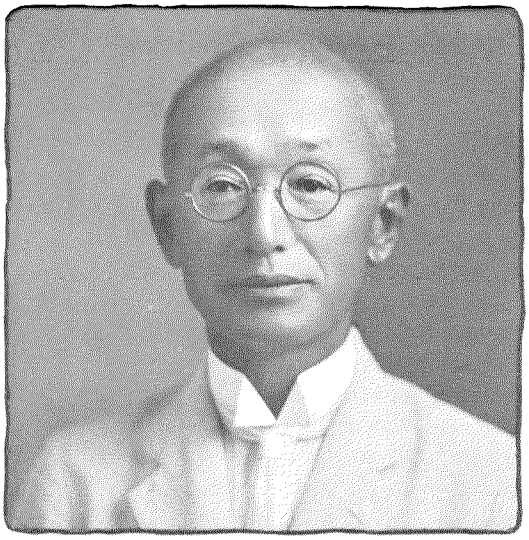


Figure 15

natural reluctance on the part of toll exchange officials to abandon a folding method which has been in use for many years and which is familiar to the operating personnel, the advantage in changing to the newer method is considered more than sufficient to compensate for any temporary inconvenience. Experience has shown that within about eight days the exchange personnel becomes fully conversant with the method of operating the new system. The fact that it is simple in operation and the tickets do not undergo any deformation in traveling through the tubes of course facilitates its introduction.

A new Mix and Genest vacuum receiving valve has been working at the Toll Exchange at Bielefeld since December, 1930, to the entire satisfaction of the Postal authorities. The Toll Exchange at Genoa will be equipped with six receiving valves of this type. The advantages of this new valve are simplification in design, increased reliability in operation, reduced cost of installation and easier supervision inasmuch as the valves project only twenty-five centimeters (ten inches) above the table.

IN MEMORIAM



MR. KANKICHI YUKAWA

A Brief Biography of Mr. Kankichi Yukawa

THE late Mr. Kankichi Yukawa was born on the 24th of May, 1868, in Shingu, a small country town in Wakayama Prefecture, Japan. ¶ In 1896 he was chosen as one of the Japanese delegates to the International Postal Conference held at Washington. On his way back he visited Europe, inspecting the industrial and commercial conditions there. ¶ On his return, he was appointed Director of the Tokyo Communications Bureau, and a Councillor to the Department of Communications and to the Department of Foreign Affairs. ¶ In 1898, he was made Principal of the Postal and Telegraph Officers' Training School, where he won the love and respect of his students. His efforts during his years of service there were fully repaid, for many of his students have become prominent figures in the telephone and telegraph field in Japan. ¶ In February, 1905, he retired from the Civil Service and joined the Sumitomo firm, where he began his new career as Manager of the parent company of all of the Sumitomo concerns. ¶ In 1910, he was nominated one of the Directors of the Sumitomo Goshi Kaisha. He was also appointed Manager of the Sumitomo Steel Tube and Copper Works. Under his supervision and management the Sumitomo Steel Tube and Copper Works enjoyed great prosperity and made great strides on the technical side. ¶ The wire plant which was started as one of the departments of the Sumitomo Steel Tube and Copper Works became a separate company at his initiation, and was established as an independent plant in August, 1911. ¶ In 1912, he was elected Director of the Sumitomo Bank, Limited, became its Managing Director in 1915, and remained in that capacity till 1925. ¶ In the fall of 1918 he made his second trip to America. He availed himself of this opportunity to negotiate an agreement with the International Western Electric Company, Incorporated, (now the International Standard Electric Corporation). In February, 1919, he carried on various negotiations which resulted in a successful association with the Bell System and the International Western Electric Company, Incorporated, and the Nippon Electric Company, Limited. ¶ The Sumitomo Electric Wire and Cable Works was incorporated under the Japanese laws as a limited company with Western participation through the Nippon Electric Company. This participation was taken over by the International Standard Electric Corporation in 1925. ¶ In October, 1925, he succeeded the late Mr. K. Nakada as Director General of the Sumitomo Goshi Kaisha. He retired from this position, and was succeeded by Mr. M. Ogura, remaining as Adviser to the Company. ¶ Mr. Yukawa was a Member of the House of Peers, to which he was appointed by the Emperor in December, 1930. He was also a member of many associations and committees formed for the purpose of industrial and economic investigation and development in Japan. ¶ In his private life, Mr. Yukawa was known as the pioneer of golf in Japan, and was President of the Ibaraki Golf Club. He was highly esteemed for his sportsmanship and greatly admired by all who came in contact with him, for his many excellent qualities. ¶Mr. Yukawa succumbed to pneumonia on August 23, 1931.

An Automatic Device for Recording, Correcting and Analysing Articulation Results

By JOHN COLLARD, Ph.D.
International Telephone and Telegraph Laboratories, Incorporated

SINCE a telephone circuit is designed primarily to transmit speech from one place to another, the articulation test, which gives a measure of the success with which the circuit functions in this respect, is of considerable importance in the design and development of telephone apparatus and in fundamental studies of speech.

Unfortunately, the articulation test is lengthy and is particularly subject to errors due to the human element. In consequence, work has been in progress in the International Telephone and Telegraph Laboratories with a view to reducing the length of time required for a test and eliminating as far as possible the effect of the human element. One result of this work has been the development of an electro-mechanical device for recording, correcting, and analysing of articulation test results. This device, which has been called the articulation recorder, not only materially reduces the time required for correcting and analysing results, but also eliminates the errors which are so apt to occur when these operations are carried out by manual labour. In order to make clear the operation of this device and the benefits resulting from its use, a short description is first given of the way in which an articulation test would be carried out by manual labour only. The construction of the device is then described and finally a short account is given of its use together with a discussion of its advantages.

Articulation Technique

When it is desired to measure the articulation of a given telephone circuit a crew is used which may consist of any number of testers from two upwards, although for accurate and reliable results at least nine testers are desirable. One of these is used as a caller at the transmitting end of the circuit while the remainder act as listeners at the receiving end of the circuit.

The ordinary speech sounds, vowels and consonants, are taken and formed at random into pronounceable syllables. These syllables may be of various forms but the most common type is that consisting of an initial and final consonant with a vowel in between, e.g., *BIK*. Random syllables, rather than actual words or sentences, are used in order to avoid guessing on the part of the listeners.

The caller calls these syllables over the circuit one by one and the listeners write down what they think each syllable is. The list of syllables written out by each listener is then taken and corrected by comparison with the list actually called. In some cases, the articulation of the circuit is taken as the percentage number of syllables correctly received over the circuit. In other cases, the articulation is taken as the percentage number of individual speech sounds correctly received.

In one system used in the laboratories, packs consisting of 80 cards are used and each card has a different syllable typed on it. Half these cards have a syllable of the form consonant-vowel-consonant, one quarter of the form vowel-consonant and one quarter of the form consonant-vowel. Hence the total number of speech sounds used in forming these 80 syllables is $40\times 3+40\times 2=200$. Other systems employing only one type of syllable are also in use and the articulation recorder can be used equally well with any of these systems. In this description the application of the recorder to the system using different types of syllables has been dealt with.

In order to show the considerable amount of work involved in correcting and analysing the results of an articulation test, let us take the case of the packs mentioned above which contain 80 syllables composed of 200 speech sounds. Assume also that a crew of nine testers is being used and that a test consists of each tester calling in turn to the remaining eight. At the end of the test there will be $80\times 9\times 8=5{,}760$ syllables and

$200 \times 9 \times 8 = 14{,}400$ sounds to be examined and corrected. Furthermore, for certain fundamental studies, it is desirable to know not merely the average sound articulation but the articulation for each individual speech sound. This means that, instead of obtaining only one value of articulation for each test, 37 different values must be worked out since 22 different consonants and 15 different vowels are used in the syllables.

These figures will give an idea of the very large amount of labour required in correcting articulation lists. Bad handwriting of the listeners often adds to the difficulty of this work. When this correction work is carried out by manual labour, it will be obvious that apart from the very considerable amount of time involved, there are many opportunities for errors to occur.

Description of Articulation Recorder

This device has been designed to carry out the recording, checking, and analysing of the listeners' results mechanically with a minimum of effort on the part of the operators. Since in some respects the device replaces the conscious thought of the operators, it has some rather complicated operations to carry out. In this short description, therefore, it is impossible to go into all details, but sufficient information is given to explain the fundamental principles and to demonstrate the most interesting features.

Outline of Method of Operation

Since several hundred packs of cards of the type mentioned in the previous section had already been prepared for use in articulation testing before the articulation recorder was developed, it was decided to make use of these same cards for the recorder.

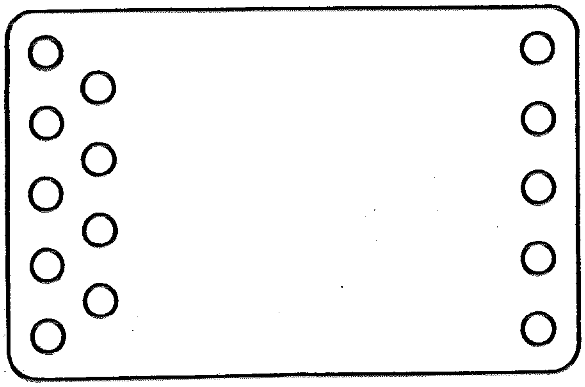


Figure 1—Card with Holes Punched According to a Definite Code.

The device is arranged to display the cards of a pack one by one to the caller at the correct rate so that he can call the syllables printed on them. At the same time, it is necessary to communicate to the recording device what each syllable is. This has been done by punching holes in each card according to a definite code. These holes are illustrated in Figure 1, which shows a card punched with three vertical rows of holes. The first row consists of five holes and corresponds to the first consonant of the syllable, the second row contains four holes and corresponds to the vowel, while the last row contains five holes and corresponds to the last consonant. In any given case, of course, only some of the holes in each row would be punched depending on the particular sounds composing the syllable. For syllables of the form consonant-vowel the last row of holes is not used at all, while for syllables of the form vowel-consonant the first row of holes is not used. The reason that only four holes are used for the vowels while five are required for the consonants is that only 15 different vowel sounds are employed in forming the syllables while 22 consonants are used.

The cards are passed through a device arranged so that as each card is displayed to the caller, 14 small contacts are pressed on to the card in positions corresponding to the 14 holes. If a hole has been punched in a card opposite to a given contact, the contact passes through the card and touches an earthed contact on the other side. If no hole has been punched opposite a given contact, the contact merely remains pressed against the card and is therefore insulated from earth.

The further action of the device is illustrated in very much simplified form in Figure 2. Here the card C is represented in cross section resting on an earthed plate P. Only three contacts are shown and of these the first and third have holes opposite them in the card, thus enabling them to pass through and touch the earthed plate. The second contact has no hole opposite it and therefore remains insulated.

Each contact is connected to the winding of a relay and an earthed battery is connected in parallel to the other terminals of the relays. Consequently, when a contact is earthed, the relay to which it is connected operates. The first relay has one changeover contact as shown in Figure 2, the second has two, the third has four and, if there were other relays as in actual practice, each relay would have twice as many contacts as the one before. The contacts are connected in the way shown in Figure 2, the final contacts being connected to a series of message registers. The result of this connection is that by operating the appropriate relays it is possible to connect the earthed point *A* to any one of the message registers. In the case shown in Figure 2, in which only the first and third relays are operated, the point *A* is connected to the third message register. Each message register is connected to a corresponding key which, when closed, connects an earthed battery to the message register. These message registers are of the ordinary type used in exchanges for recording the number of subscribers' calls. It will be seen from the diagram that if the key connected to message register No. 3 is pressed, current will flow via the earthed point *A*. The message register will, therefore, pull up and register once. If any of the other keys are pressed, nothing happens since there is no complete circuit.

The operation of the device is as follows: Suppose that the particular punching illustrated in Figure 2 corresponds to the sound $\bar{E}$. Then message register No. 3 would also correspond to the sound $\bar{E}$ and would be marked accordingly. Each of the other message registers would, of course, correspond to one of the other sounds and, in actual practice, there would be 37 message registers to correspond to the 37 sounds, 15 vowels and 22 consonants, employed. The keys are placed in front of the listener and each key is marked with the same sound as the message register to which it is connected. In our example, therefore, the third key is marked $\bar{E}$. The card would also have $\bar{E}$ printed on it and the caller would thus call this sound over the circuit. If the listener receives the sound correctly, he presses the corresponding key, i.e., the third one, and, since by reason of the holes punched in the card the point *A* has been switched to the third message register, a current will flow and the message register will record once. If the listener mistook the sound $\bar{E}$ for some other one, e.g., $\bar{I}$, he would press the key corresponding to $\bar{I}$ and nothing would happen. The result is, therefore, that every time the listener receives a sound correctly and presses the correct key, the fact is recorded on the corresponding message register. By noting the readings of all the message registers before and after a test, it is thus possible to determine how many times each sound has been correctly received. Then, by knowing how many times each sound occurs in the test pack, the percentage articulation can be worked out.

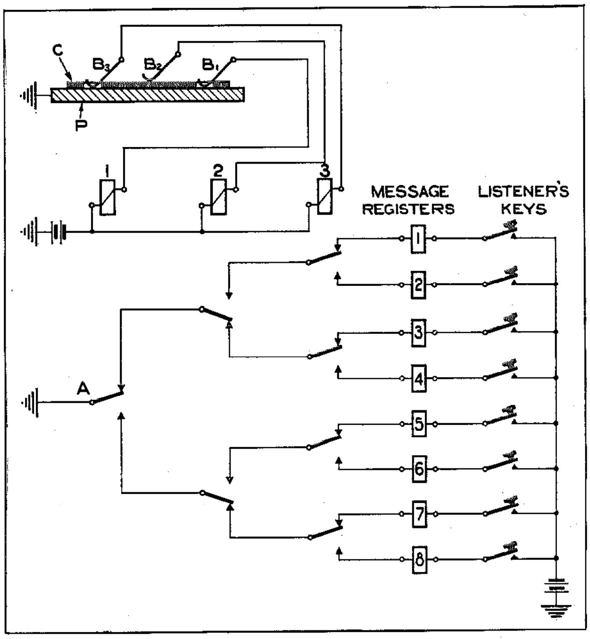


Figure 2—Simplified Schematic of Automatic Device for Recording, Correcting, and Analysing Articulation Results.

Electrical Details

A general idea of the fundamental principles of the articulation recorder will have been obtained from the preceding description. In addition, a number of particulars in connection with the electrical part of the device are of interest.

In the actual recorder there are three separate banks of relays connected in accordance with the method illustrated in Figure 2 and corresponding respectively to the first consonant, vowel, and second consonant of the syllable. This is illustrated in diagrammatic form in

Figure 3 where the relays and their contacts are represented by triangles. Connected to each is shown one message register and one key for each of two listeners. This is merely to simplify the diagram; actually, of course, there would be 22 message registers and keys attached to the first bank of relays, 15 to the second and 22 to the third, and there would be this number for each of the listeners. The device is arranged to be extended to eight listeners.

From Figure 3 it will be seen that the message registers corresponding to the different listeners are all connected in parallel to the one set of relay banks, but it will be clear from the connections that the keys of a given listener can only cause his own message registers to operate.

A difficulty occurs in the case of the consonants due to the fact that each listener has only one message register and key for each of the 37 sounds. Since the first relay bank corresponds to the first consonant in the syllable and the third relay bank corresponds to the final consonant, both these banks have to be connected to the same set of message registers representing the 22 consonants. This is shown in Figure 3. Suppose that the points A_1 and A_3 are directly earthed as in Figure 2 and that the syllable *TAK* is called. This may very easily be mistaken for *KAT* by the listener, since *T* and *K* are very easily confused. Then the listener will first press his key *K*. There will be no path through his corresponding message register through the first relay bank since this will be set to *T*. But, since the first and third banks are in parallel and the third bank is set to *K*, there will be a path set up through the third bank which will cause the listener's *K* message register to operate. In a similar way, when the listener presses his *T* key for the final consonant this will set up a circuit through the first relay bank and cause his *T* message register to operate. The final result will be that both the *K* and *T* message registers will indicate a correct reception of these sounds although actually the listener got them both wrong.

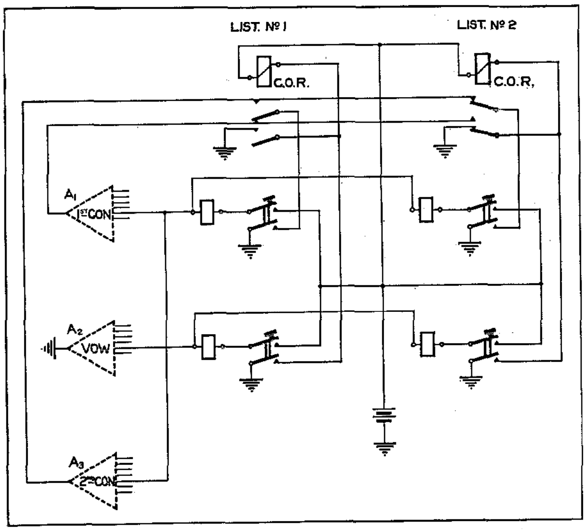


Figure 3—Recorder with Three Separate Banks of Relays Connected in Accordance with the Method Illustrated in Figure 2.

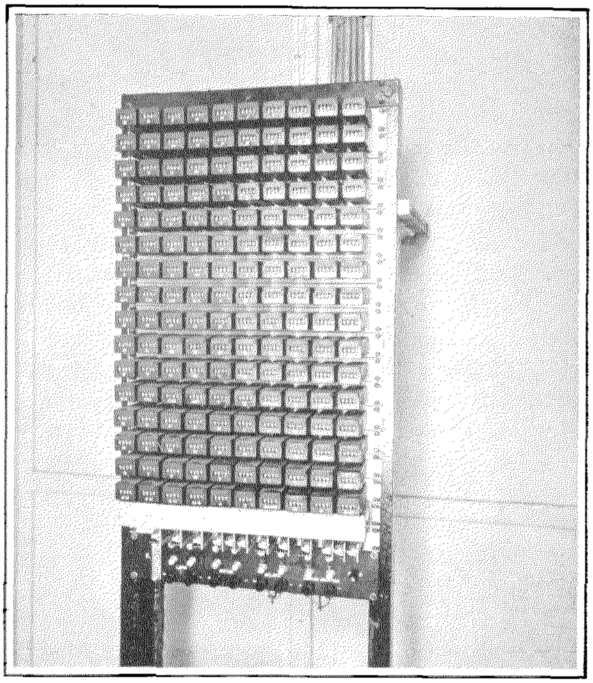


Figure 4—Bank of Message Registers.

To avoid this difficulty the points A_1 and A_3 in the relay banks are not connected directly to earth but are connected to earth via a changeover relay, shown as *COR* in Figure 3. This changeover relay normally puts earth on the first relay bank so that the first time the listener presses a consonant key it is checked only through the first bank, and not through the third which has no earth connection.

The syllables are of the form consonant-vowel-consonant so that, after pressing a consonant key the first time, the listener naturally presses a vowel key next before pressing a second consonant key. Now all the vowel keys of a given listener have a pair of contacts connected to the winding of that listener's changeover relay. Hence, as soon as the listener presses any vowel key his changeover relay operates and locks up in this operated position. This, therefore, takes the earth off the first relay bank and puts it on the third bank. The result is that the second time the listener presses a consonant key it is checked through the third relay bank, the first bank now providing no through circuit. Hence, although the first and third relay banks are in parallel, the use of the changeover relay operated from the vowel keys ensures that the listener's first consonant is checked with the first relay bank and his second consonant is checked with the third relay bank.

It will be seen from Figure 3 that the earth connections to the first and third relay banks are applied through contacts on the consonant keys. This is because, if the earth connection were applied directly by the changeover relay and one listener's relay was operated while another's was not, both the first and third banks would have earth connected to them as long as this condition lasted. It would thus be possible for a listener's key to be checked through the wrong relay bank via the earth connection applied by another listener's changeover relay.

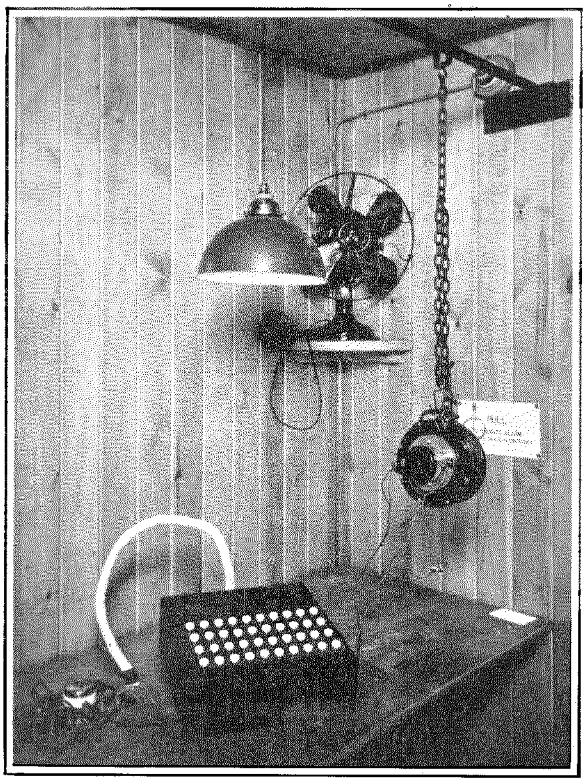


Figure 5—Keyboard Used by Listeners.

In the case of syllables of the type vowel-consonant or consonant-vowel it often happens that, on a bad circuit, the listener thinks that a second consonant was called and thus makes the syllable into the type consonant-vowel-consonant. To record this type of error a message register marked + is connected to that contact in the consonant relay banks to which the point A is switched when all the relays are unoperated, i.e., message register No. 8 in Figure 2. If, therefore, a listener presses a consonant key when a consonant is not present in the called syllable, a circuit is set up through the + message register and the latter thus operates.

In order to obtain the average sound articulation for all speech sounds, a message register marked Σ is connected in the common battery lead to all other message registers. This message register, therefore, operates every time any other message register is operated and indicates the total number of correct sounds recorded plus the number of letters added in error by the listener and recorded on the + message register. The reading of the Σ message register minus the reading of the + message register thus gives the total number of sounds correctly received.

A photograph of the bank of message registers is shown in Figure 4. This bank includes the message registers for four listeners with the selecting and changeover relays underneath. In Figure 5 can be seen one of the keyboards used by the listeners.

Mechanical Device

The external appearance of the mechanical device is shown on the left of Figure 6. The pack of cards is placed in a receptacle at the top of the device and the cards are pushed out one by one from the bottom by means of a thin ram and a gate which allows only one card at a time to pass. After being pushed through the gate,

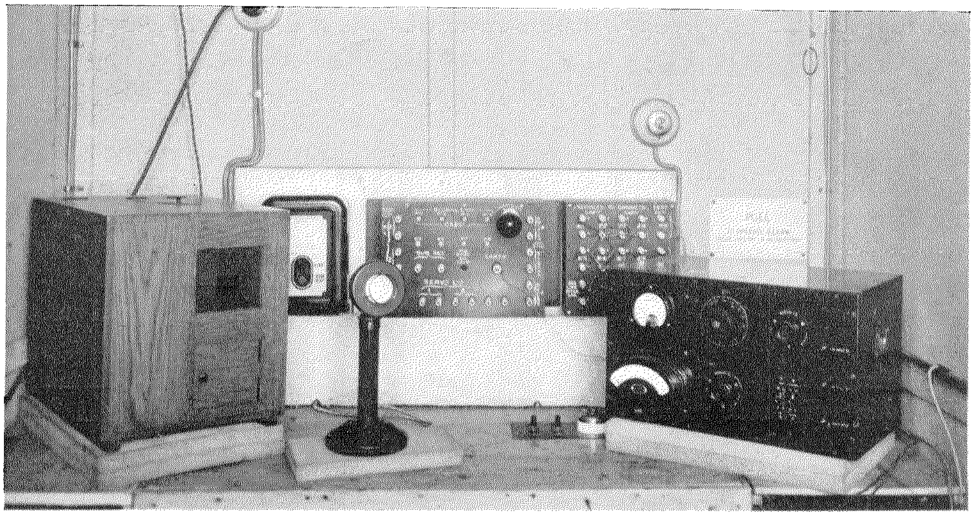


Figure 6—Card Handling Device (Shown at Left)

the card falls down an inclined shute until it reaches a stop. At the correct moment this stop is withdrawn and allows the card to slide further down until it reaches a second stop. While the card is resting on this stop, a plate carrying 14 movable contacts is pressed up against the card so that, where a hole has been punched in the card, the corresponding contact passes through and touches a second contact above the card. These upper contacts are connected to the relay windings of the three relay banks. While this is taking place, a second card has been pushed through the gate and has been held up by the first stop. After sufficient time has elapsed to enable the caller to call the syllable and for the listeners to press their keys, the second stop is removed and the card falls into a second receptacle. The second card then falls into position and the cycle of operations is repeated. The stops and movable contacts are operated by a rotating cam which is driven by the same electric motor that operates the ram. The card, while in position, is illuminated by a small electric lamp and is viewed through a window in the containing box. The box is padded with felt to prevent the sound of the mechanism from interfering with the test.

Operation of the Recorder

The testing routine using the articulation recorder is very similar to that used in an ordinary articulation test. The card handling device is located in front of the caller so that he can see the cards as they appear and at the same time keep his mouth at the correct position with reference to the microphone. The speed of calling is, of course, controlled by the speed with which the cards are passing through the device and this in turn is controlled by varying the speed of the operating motor. The listener, on hearing the syllable transmitted over the circuit which is being tested, merely has to press the appropriate keys.

Before the test is begun the readings of the message registers are noted down and again after the test is finished. In order to save still further time, the message register bank can be photographed before and after the test in order to obtain a record of their readings. In order to check the correctness of the whole recorder operation a special test pack is put through at the beginning of each day. This pack contains all the sounds in a definite order known by the listeners, so that as each card of this pack passes through the card handling device, the listeners are able to press the correct keys. If the device is operating correctly, there should be no mistakes indicated at the end of the check test. At first, of course, slightly more effort is required by the listeners when using the recorder since, instead of merely writing down the syllables, they have to look for the correct keys to press. In actual practice, however, it has been found that the listeners very soon become accustomed to the keyboard and very much prefer its use to the old method of writing down the results.

Conclusions

The use of this articulation recorder, by reducing the amount of effort required by the caller and listeners, enables them to carry out the test with less fatigue and, therefore, with greater accuracy. The really great advantage of the device, however, lies in the fact that the moment each test is finished the results are produced completely corrected and analysed. It is estimated that to carry out this work by manual labour would require about 20 man-hours for each complete test with a crew of nine operators. This means that, in addition to the heavy cost of this work, there is always considerable delay in the production of the final results. By the use of the articulation recorder both this cost and the delay are avoided and, since both the correction and analysing are carried out entirely automatically, the errors which inevitably occur with manual labour are avoided. Thus, the recorder has been of very material assistance in enabling the laboratories to establish a satisfactory technique for the accurate measurement of articulation.

Modern Loading Equipment

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EDITOR'S NOTE: *Because of lack of space this paper is printed in part in this issue and will be concluded in the April issue of* ELECTRICAL COMMUNICATION. *The part now printed deals primarily with loading coils; the remaining part will deal with loading coil cases.*

THE object of this paper is to give a general description of the equipment being used for the loading of telephone cables in Europe, and to trace briefly the lines along which the present product has been developed as well as to indicate the relationship which it bears towards transmission problems.

The history, theory, and general principles of the subject are fully dealt with in the now classic paper[1] presented by T. Shaw and W. Fondiller at the A. I. E. E. convention in February, 1926. Other literature on the subject is given in the bibliography at the end of this article.

Elementary Design

In order to follow the various stages of evolution resulting in present day equipment it is necessary to have some knowledge of the general principles of practical design, and the following paragraphs are intended to give briefly an indication of some of the salient features.

It is not possible to set down a rigid method of design since the line of attack to be followed in any case is dependent upon the form in which the final result must be delivered. Thus it may be necessary to produce a coil of fixed dimensions, a coil of defined electrical characteristics, or a coil having the most economical combination of both those factors, and in none of the three instances is it possible to follow the same design procedure. It should be remembered, therefore, that the following design features do not occur in any fixed order but must be looked upon as a group having complete mutual relationship in which the complete definition of any one member puts certain limitations on the other members.

As is well known, a loading coil consists of a toroidal shaped core of magnetic material upon which the windings are placed in the necessary inductive relationship.

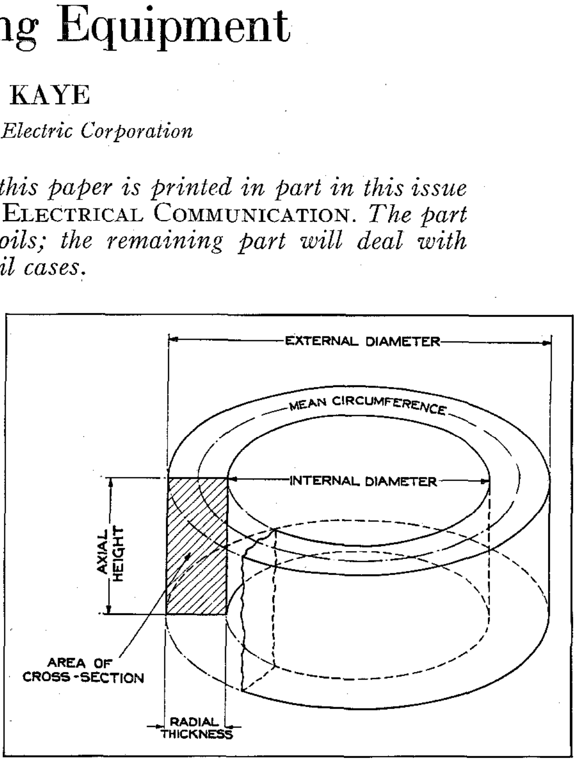

Figure 1—Loading Coil Core Dimensions

The effective permeability of the magnetic material of a core of given dimensions defines the number of turns of wire which are required to attain a given inductance value.

The iron losses occurring in the core when an alternating current is applied to the windings, increase both with increase of current and frequency.

Since the permeability and iron losses are intimately related, an increase in permeability generally being accompanied by an increase in the iron losses, it is necessary to ascertain the maximum iron losses permitted when the coil is in operation and then to use a material having the highest possible permeability under the required conditions.

If a suitable material of known permeability is available the next step is to choose convenient core dimensions only two of which have any influence over the electrical characteristics of the coil. These are the mean length of magnetic circuit which corresponds approximately to the mean circumference of the toroid and the area or cross-section of magnetic material enclosed by a turn of winding. (See Figure 1).

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[1] "Development and Application of Loading for Telephone Circuits," *Electrical Communication*, April, 1926.

Since the circumference is of fixed dimensions the only radical changes which can be made in the shape of a core are those of the perimeter enclosing the cross-section.

In order to enclose the maximum area with the shortest turn of wire around the core it is obvious that the best shape for the perimeter would be a circle, but practical considerations at times preclude the use of such a core; for example, if the core material gives its best performance when built up in laminated form the only feasible shape is rectangular or, if the external and internal diameters of the wound coil are limited owing to exigencies of horizontal space, it may be necessary to increase the length of core section in an axial direction.

One of the most useful assumptions which may be made regarding core dimensions is that, provided the ratio of mean circumference to area of cross-section is kept constant, the number of turns required to secure a given inductance remains constant no matter what volume of core material is embodied in the core. Still more important, within certain practical limits, is that no change takes place in the direct current resistance of the complete winding. The reason for the latter occurrence is that although it may be necessary to reduce the wire gauge in order to accommodate the required number of turns of wire on a smaller core, the total length of wire required is also reduced and the effects on the direct current resistance approximately annul each other.

The limit of the above assumption of constant direct current resistance is reached when the ratio between the area of copper and of insulation which together comprise the total area of cross-section of the winding material, begins to vary by an appreciable amount.

From the preceding it would appear possible to construct coils of small dimensions limited only by the design of the winding machine and the ability to prepare wire having a sufficiently thin coating of insulation. Unfortunately such is not the case.

As the area of cross-section is reduced, the

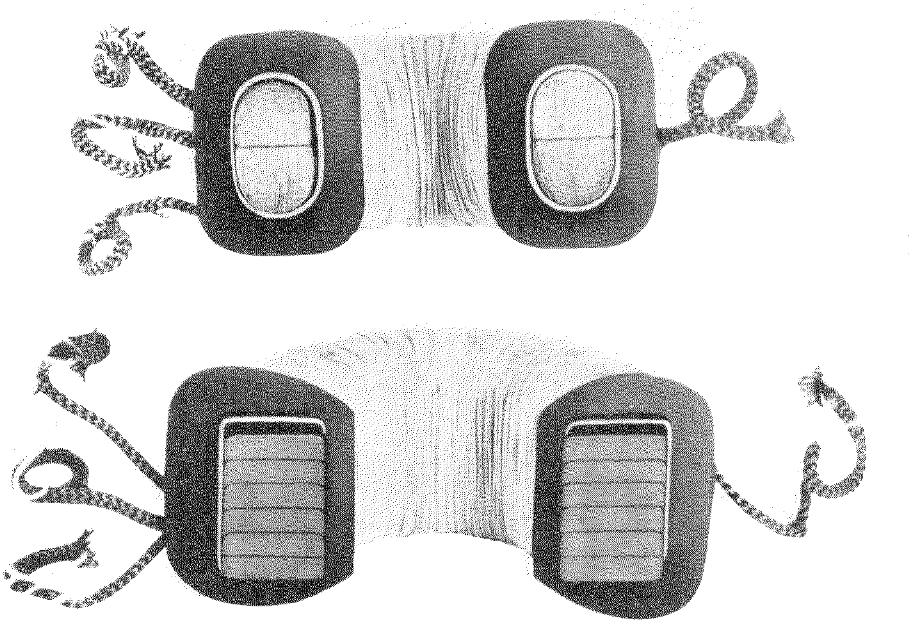

Figure 2—Small and Large Iron Dust Cored Coils

flux density in the core material increases and is accompanied by increased iron losses in the core. These losses are evidenced first by an increased rate of change of effective resistance with change of operating current and finally by a complete magnetic saturation of the material, thus rendering the coil inoperative. At the same time the rate of change of effective resistance with frequency increases.

The Evolution of Different Types of Coils

Apart from the well-known German product, fully described elsewhere, the loading coils used in European cables up to the end of the year 1925 had been identical with those manufactured and used in the United States of America.

Towards the end of 1925 the British Post Office announced its intention of loading exchange area cables and, since no phantom circuits were to be used, the coils for the purpose were not required to have the same standard of electrical precision as those used for the side circuits of long-distance phantomed circuits, whilst the lower grade of transmission required on the exchange area circuit enabled this depreciation in electrical quality to be still further extended.

There were, however, two very important factors to be secured on the coil: first, it had to be cheap in order to merge economically into the exchange area cable system and, second, it had to be small in order to permit the installation of a large number of coils in the restricted space available in city manholes.

The limitation of cost at once emphasised the difference existing between the European and American values for the ratio of cost of labour to cost of material. In other words, assuming that the coil dimensions had reached a stage such that any reduction therein required increased time of manufacture, then the most economical coil produced in Europe would have different dimensions from those of the equivalent coil produced in America.

As the result of preliminary cost study, an exhaustive study of coil design was undertaken with particular reference to European conditions. The limited time available for the completion of the coil did not permit extending the investigation into the field of core materials so that the choice was limited to the materials already at hand and fully described in a paper[2] by B. Speed and G. W. Elmen.

After the survey of trial designs it was considered advisable not to deviate from the standard compressed iron dust material referred to in the above paper as the Grade "B" type and having a permeability of 32. With this material as a basis the final design gave a coil having a volume of approximately two-thirds of that of the normal side circuit coil in general use. A comparison of the two coils is seen in the sectional view of Figure 2.

This coil was put into operation and found very satisfactory with a tendency, if anything, to be more efficient than necessary. The latter point was investigated and found to be due to the fact that, notwithstanding an increase in flux density, the corresponding increase in the total iron losses per unit volume had been practically linear; furthermore, since the volume of magnetic material had been reduced, the total iron losses for the coil compared favourably with those obtained on the standard side circuit coil.

Now the main structural difference between the exchange area coil and the long distance side circuit coil was that the latter had the balanced windings essential to phantom group working but unnecessary for the purpose for which the smaller coil was intended. Full advantage had been taken of the increase brought about in the effective winding area by the use of a simple winding but it was believed that the technique of winding had not been extended to its limit and it might be practicable, therefore, to produce a coil identical in size with the exchange area coil but with balanced windings. It was found possible to construct such a coil without much difficulty and its properties were found to be very little different from the larger side circuit coil apart from the increased flux density under which it would have to operate.

The transmission characteristic which is most affected by the use of coils working normally at a high flux density is that of the sensitivity to interference from a superposed circuit. Hence, the possibility of using the small balanced coil

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[2] "Magnetic Properties of Compressed Powdered Iron," *Proceedings* A. I. E. E., June, 1924.

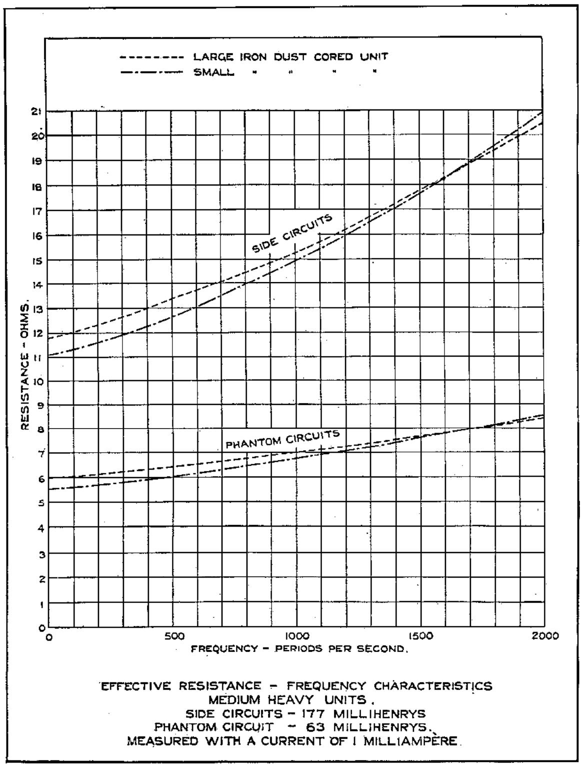

Figure 3—Effective Resistance—Frequency Characteristics Medium Heavy Units

under conditions of superposed currents was considered with a view to associating it with a phantom coil so as to provide a unit which would replace the large unit in use at the time.

The large unit had been designed not only when little was known about the methods of studying superposed current effects but also when the actual values of superposed currents in composite circuits could not be specified with any degree of certainty as to future requirements. Since composite circuits were certain to increase, any attempts at size reduction had to be sacrificed to the unknown, and the volume, which is approximately proportional to the inverse of the squared flux density, had therefore to be given a value such as would provide an ample factor of safety in this respect. However, at the time when the results on the smaller coil were indicating its unexpected efficiency, much more information was available both on the effects of superposed currents and their probable maximum values.

As a result of a study of these factors it was evident that the increase of flux density due to the reduction in volume together with the increase due to the probable maximum superposed current would result in an operating flux density which was still insufficient to produce undesirable modulation effects.

A small phantom coil was designed to work along with the balanced side circuit coils which had been evolved from the exchange-area coil, and the resulting unit of one phantom and two side circuit coils had a volume approximately two-thirds that of the unit then being used for long distance cables. The two curves in Figure 3 show the characteristics of a medium-heavy unit of this type alongside those of the unit which it replaced whilst Figures 4 and 5 show the relative dimensions of the units and of cases containing equivalent quantities of units.

The small unit when in operation justified the faith which had been placed in its ability to replace the larger unit in every respect.

There is one point which is worthy of emphasis and that is that the sensitivity of a coil towards superposed currents is in no way directly connected with its ability to recover its initial condition after a sudden magnetic shock or some temporary abnormal magnetic conditions. Such recovery ability appears to be an inherent property of the material composing the core and has no connection with the mechanical dimensions of the core except in so far as a core of small volume naturally attains a condition of complete saturation sooner than a larger core. After the saturated condition has been reached the period of recovery is practically the same in either case.

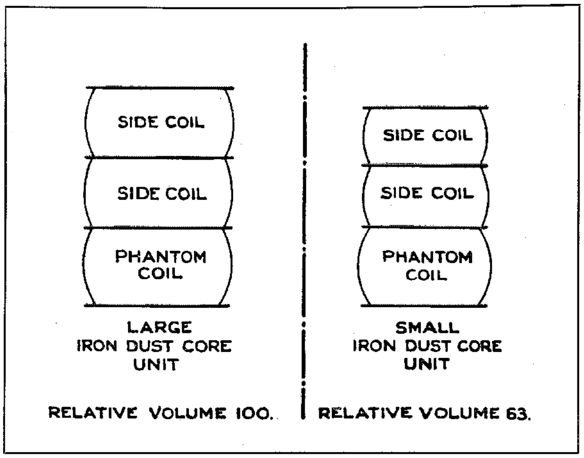

Figure 4—Comparative Sizes of Iron Dust Cored Loading Units.

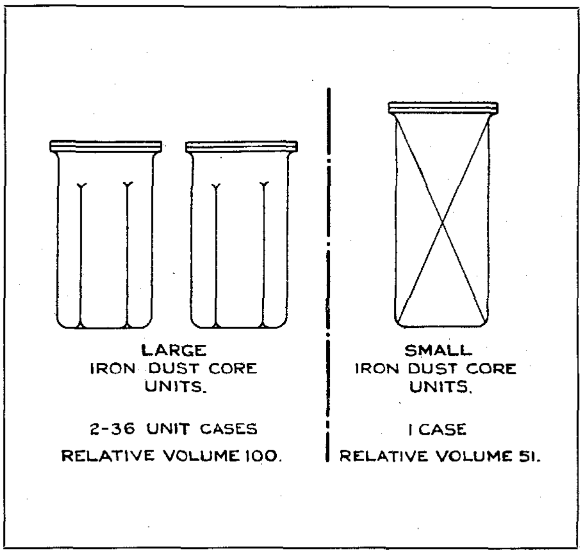

Figure 5—Comparative Sizes of Equipment for Encasing 72 Loading Units of Iron Dust Cored Types.

Thus, from a standpoint of magnetic stability, both the units referred to were identical. During the period existing between the inception of the new unit and that stage of development required for use in the field another problem connected with the loading unit was being attacked, namely, that of crosstalk, it having been felt for some time that the crosstalk added by the loading equipment to a complete system was excessive as compared with that added by the other units of the system. The method of attack was to isolate the individual sources of crosstalk, to investigate the most suitable means of measuring the crosstalk emanating from each source and finally to devise equipment and technique whereby the causes of crosstalk could be avoided or annulled by means of auxiliary equipment.

The sources of crosstalk may be divided into three distinct groups, namely, inductance unbalance, resistance unbalance, and capacity unbalance. The resultant crosstalk is eliminated as far as possible by winding construction, by selection, and by auxiliary apparatus.

The decrease in crosstalk resulting from the application of the new procedure was found to be considerably greater than had been anticipated, not only for near-end but also for far-end crosstalk, since the method of reduction was simultaneous in its application to both directions of interfering noise between circuits. A glance at the following table will indicate the improvement attained.

AVERAGE VALUES OF CROSSTALK FOR A NUMBER OF LOADING UNITS

	Medium-Heavy Units		Extra-Light Units	
	Old Method	New Method	Old Method	New Method
Phantom to Side Crosstalk within units.				
Near End....	27.9	11.1	24.5	8.9
Far End......	56.0	12.0	49.0	9.2
Side to Side Crosstalk between all adjacent circuits.				
Near End....	11.2	4.0	9.7	3.4
Far End......	....	3.8	....	3.6
Phantom to Phantom Crosstalk.				
Near End....	11.4	3.0	12.6	4.2
Far End......	....	4.1	....	4.2

The medium-heavy units have inductance values of 177 millihenrys for the side circuits and 63 millihenrys for the phantom circuits, the corresponding values for the extra light units being 44 millihenrys and 25 millihenrys.

Unfortunately the information on far-end crosstalk for the older units is not complete but it may be assumed to be comparable in value with the near-end crosstalk for the same circuit.

The values in the table are given in terms of units of crosstalk, one unit being defined as one-millionth of the current flowing in the disturbing circuit. Assuming the impedances of the disturbing and disturbed circuits to be equal with four units of crosstalk between two correctly terminated circuits, the disturbing current in the disturbed circuit will be four-millionths of the total current in the disturbing circuit.

The above crosstalk values which cover sufficient measurements to produce reasonably average figures were obtained at a frequency of 800 p.p.s., with a current of 10 milliamperes flowing in the disturbing circuit. Not only do these values emphasise the improvement in the product itself but they are also indicative of the improvement which has taken place in the apparatus used for measuring the crosstalk in that product. Factory testing is now carried out to the nearest unit of crosstalk whereas in the past it was not possible to measure more accurately than to the nearest five units of crosstalk.

In addition to refinement of the apparatus used for the final measurements of crosstalk, it was necessary to evolve entirely new apparatus for the factory measurements of the electrical components causing crosstalk in order to enable their direct annulment without recourse to trial and error methods and consequent waste of time.

The new unit and the new method of crosstalk reduction were completed simultaneously thereby providing equipment which has the same general characteristics as that in immediate use but possessing the two advantages of reduced dimensions and lower crosstalk. It will therefore be seen that a stage had been reached in Europe at which, using existing materials, the most economic unit had been produced.

Only three things could occur to upset the economic equilibrium thus secured, these being, a change of considerable magnitude in labour conditions, a change in the requirements of the telephone system, and a change in the electrical properties of the materials from which the coils were constructed.

The first factor was unlikely to happen, the second gave no indication of change, and the only possibility of variation lay, therefore, with the third. Fortunately a change in the latter factor was forthcoming in the most fundamental feature of the coil, namely, the core.

Loading Coils with Permalloy Cores

Experience in the use of pure iron dust as a core material over a period of twelve years had indicated that it was unlikely that any revolutionary changes in its permanent electrical properties could be secured either by treatment or mechanical mixture, but about the year 1921 it was discovered that one of the nickel-iron alloys possessed remarkable magnetic properties. The alloy in question known as "Permalloy" was found to have an exceptionally high permeability and small hysteresis losses at low magnetising forces such as prevail in telephone work.

While certain magnetic properties were emphasised, it was unfortunately found, as might have been expected, that the effects of external changes such as heat and mechanical stress were also very much in evidence so that the material as at first produced was unsuitable as a commercial substitute for magnetic iron.

As the result of research work in the Bell Telephone Laboratories, a technique was developed whereby it was found possible to use the new alloy for continuous or Krarup loading, which consists of wrapping a magnetic material around the copper conductor in a cable and thus increasing the magnetic field around the conductor. Owing to the fact that it is possible to add only a small value of inductance by means of continuous loading, such a practice is uneconomical except for submarine cables where it is impractical to use coils in cases at extreme ocean depths.

Up to 1924 magnetic iron had been the only suitable material available for continuous loading and owing to the very small inductive effect it had not proved a success economically. With the inception of permalloy, however, the situation was completely changed and it was found possible to construct cables capable of working at three times the telegraph speed attained in the past. The first permalloy loaded cable was laid in 1924 between New York and the Azores.

The next step was to investigate the application of permalloy to the cores of loading coils. It is of interest to note that this was practically the first instance in the evolution of loading coil development which was brought about by the occurrence of an external factor as distinct from a demand for development as a result of system requirements.

Compared with iron dust core material the homogeneous permalloy possessed two superior features and one disadvantage, namely, the hysteresis losses were lower and the permeability was greater but the ability to withstand permanent change as the result of magnetic shock was very much less. This last factor precluded the use of the straight metal.

In view of the degree of success obtained with compressed iron dust cores it was reasonable to suppose that compressed permalloy dust cores would offer a promising line of development and this supposition was fully realised.

Although a permalloy dust core, as in the case of an iron dust core, consists essentially of magnetic particles individually coated with an insulating covering, both the sources and the treatments of the two metals are widely divergent.

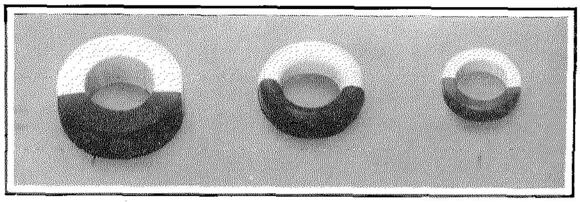

Figure 6—Comparative Sizes of Large Iron Dust Core, Small Iron Dust Core, and Permalloy Dust Core (Stanelec).

One of the major requirements for the comminution of a material is that it should be brittle. In the case of iron it was obtained in a brittle and pure condition by means of electrolysis but in the case of an alloy such a method is obviously impracticable. With permalloy it was found necessary to resort to pouring without deoxidising and to hot rolling in order to obtain the material in a suitable condition for attrition.

To produce a unit suited to European conditions, work was begun in England on the basis of the preliminary investigations on permalloy dust carried out in America. The permeability of the material was made as high as possible without increasing the iron losses beyond the limit set by the requirements of the system. It was found possible to use a material having a permeability more than twice the value of that used for the iron dust cored coils although, as might be expected, the use of such a high permeability material called for a careful control of its manufacture and a close watch on the quality of the raw materials involved.

The unit was known as the "Stanelec" No. 1, and in volume was approximately one-third of that of the smallest iron dust cored unit produced in Europe whilst its entire weight was approximately equal to that of the cores of the American permalloy dust cored unit.

Figure 6 shows the relative sizes of side circuit coil cores of the large iron dust type, the small iron dust type, and the permalloy dust type (Stanelec). The relative dimensions of the associated phantom coil cores are similar.

The electrical characteristics of the Stanelec unit are an improvement over those of any unit hitherto produced for use on the same transmission systems.

One of the most marked features has been the lack of susceptibility to magnetic shock, although the straight permalloy is much more sensitive to such treatment than is pure iron. Permalloy dust cores have a susceptibility approximately one-fifth that of the iron dust cores. The graph in Figure 7 shows a comparison of the behaviour of the two types of core when subjected to a complete magnetic cycle, the maximum current passed through the coil windings being approximately 3 amperes.

Figures 8 and 9 give comparisons of the effective resistance versus frequency characteristics for medium-heavy and extra-light units, respectively, for the three types of unit already discussed, namely, the large iron dust cored unit as used in both Europe and America, the small iron dust cored unit peculiar to Europe

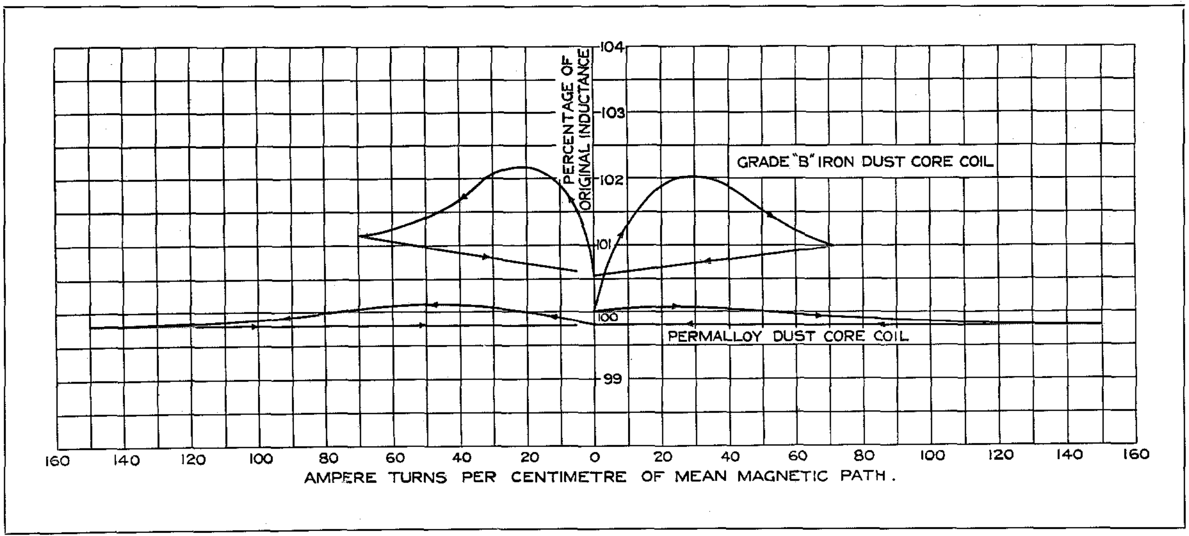

Figure 7—Residual Effect of Direct Current Magnetisation on Iron Dust and Permalloy Dust Core Loading Coils.

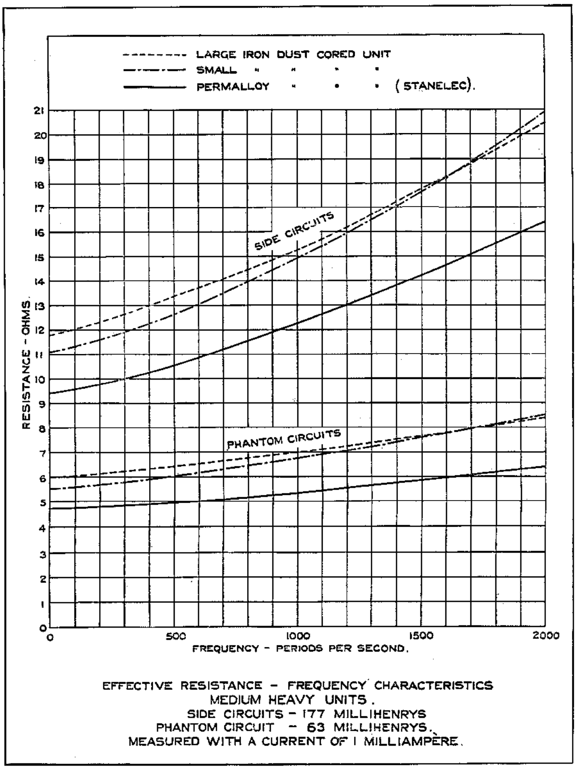

Figure 8—Effective Resistance—Frequency Characteristics Medium Heavy Units.

and the Stanelec permalloy dust cored unit for use in Europe. It will be seen that whilst the curves for the medium-heavy iron dust cored units are substantially coincident, that for the Stanelec unit indicates markedly lower values of resistance together with a somewhat less steep gradient.

It would, of course, have been possible to have reduced the size of the Stanelec medium-heavy unit still further thereby permitting the effective resistance characteristic to approach that for the iron dust cored units which it was replacing, but this would have necessitated the use of cores different from those intended for the Stanelec extra-light unit, a course presenting a great disadvantage when viewed from the standpoint of production on a large scale.

This difference in dimensions between the most economic type of unit for extra-light and medium-heavy circuits appears contradictory to the statements already made regarding the relationship between the inductance and resistance for toroidal coils, but it should not be forgotten that those statements were qualified by reference to the limiting effects of the ratio between copper and insulation areas. It is such an effect which has now come into play owing to the small dimensions of the Stanelec coil. Figure 10 gives a comparison of the relative volumes of the units in question from which this point will be readily appreciated.

It would appear that in so far as long distance coils are concerned the reduction in coil size has reached a stage at which any further attempts at reduction would unduly emphasise production costs and probably necessitate winding machine re-design as distinct from a modification of existing machines.

It may be of interest here to note the effect of reduced coil dimensions on encasing facilities. Figure 11 gives a proportionate comparison of the equipment required to encase 72 units. The volume reduction is sufficiently evident to render further comment unnecessary. The actual details of the cases are given hereinafter. Figures 12 and 13 show the winding machines used for the coils together with the belt conveyor used for carrying the coils.

Returning to the electrical characteristics of the equipment one of the most important features of the permalloy dust cored coils from the manufacturing viewpoint is the manner in which the coil inductance behaves throughout the

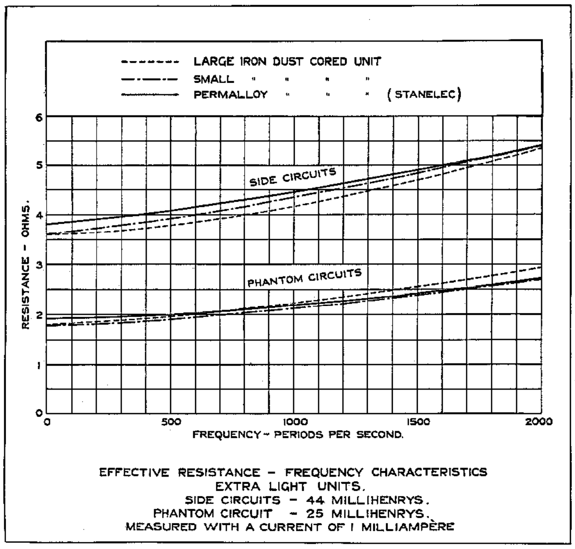

Figure 9—Effective Resistance—Frequency Characteristics Extra Light Units.

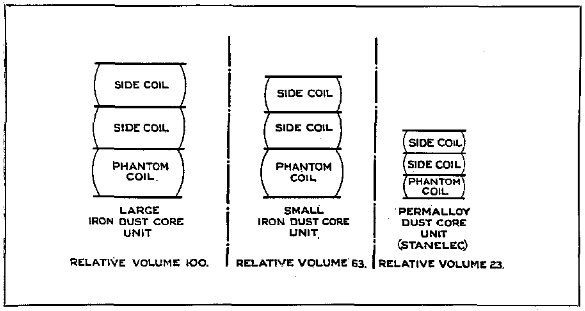

Figure 10—Comparative Sizes of Iron Dust and Permalloy Dust Core Units.

various stages of manufacture. During manufacture, particularly in the final stages, the coils are subjected to processes which may produce magnetic changes in the cores and give rise to a change in inductance. Such variations in the iron dust cores were not only fairly wide but to a certain extent were unpredictable in tendency.

In the case of permalloy dust cores the corresponding variations are very much smaller and may be predicted with accuracy thereby enabling the inductance of the coil in its final stage to be secured within very much closer limits than formerly, an advantage which was at once apparent in the singing point characteristics of the first cable to be loaded with these coils. Furthermore, after subjecting a permalloy dust cored coil to various temperature changes the inductance returns to its initial value along with the temperature, a feature rarely met with in the case of the iron dust cored coils. Similarly the change of effective resistance with temperature is less marked in the case of the permalloy dust cored coils, but since this characteristic is limited only by a maximum value it is not one of any great practical importance even if indicative of an improved product.

Another feature in which the Stanelec coils show an improvement is that of crosstalk. Two factors have been mainly responsible: first, the reduced dimensions of the coils give rise to less capacity unbalances between the associated circuits in the unit; second, the use of a core material of higher permeability restricts the boundary of the stray magnetic fields external to the coil.

In order that the reader may get a clearer view of the chief electrical characteristics desirable in loading equipment, it may be advantageous to enumerate them as in a typical guarantee for a Stanelec loading unit, but before so doing the general aspect of guarantees will be discussed.

Guarantees

In fixing the electrical guarantees for loading equipment there are three main controlling factors: first, the characteristics defined by the transmission system in which it is to be used; second, the competitive aspect; third, the standpoint of manufacture.

In the early days of loading the system requirements were confined almost entirely to the two most fundamental features, namely, the inductance of the coil and its effective resistance. Later, the introduction of the repeater emphasised certain other features which have become more important as the lines have been made longer and quality improved, until the present requirements make quite formidable reading when compared with those of the past.

Unfortunately of late years there has been a tendency for the loading equipment to be looked upon as a separate entity distinct from the associated apparatus of the system, a state of affairs which has probably been brought about by the commercial separation of the various groups of apparatus.

This outlook has resulted in the competitive emphasis of certain features in which an improvement may be quite valueless from the system aspect, thereby leading to a false evaluation of quality. From the factory standpoint any reduction of tolerance whatsoever is looked upon as an arduous infliction; nevertheless, the reaction is not without legitimate reason for it should be

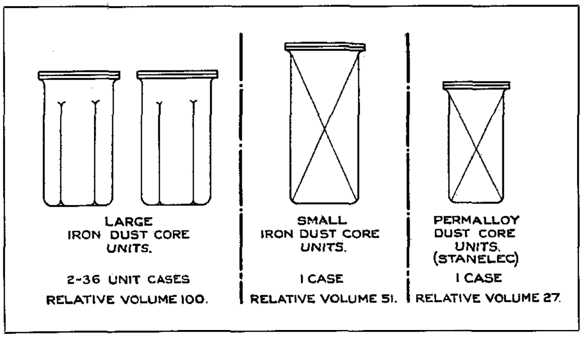
LARGE IRON DUST CORE UNITS.
2-36 UNIT CASES
RELATIVE VOLUME 100.
SMALL IRON DUST CORE UNITS.
1 CASE
RELATIVE VOLUME 51.
PERMALLOY DUST CORE UNITS. (STANELEC)
1 CASE
RELATIVE VOLUME 27.

Figure 11—Comparative Sizes of Equipment for Encasing 72 Loading Units of Iron Dust and Permalloy Dust Core Types.

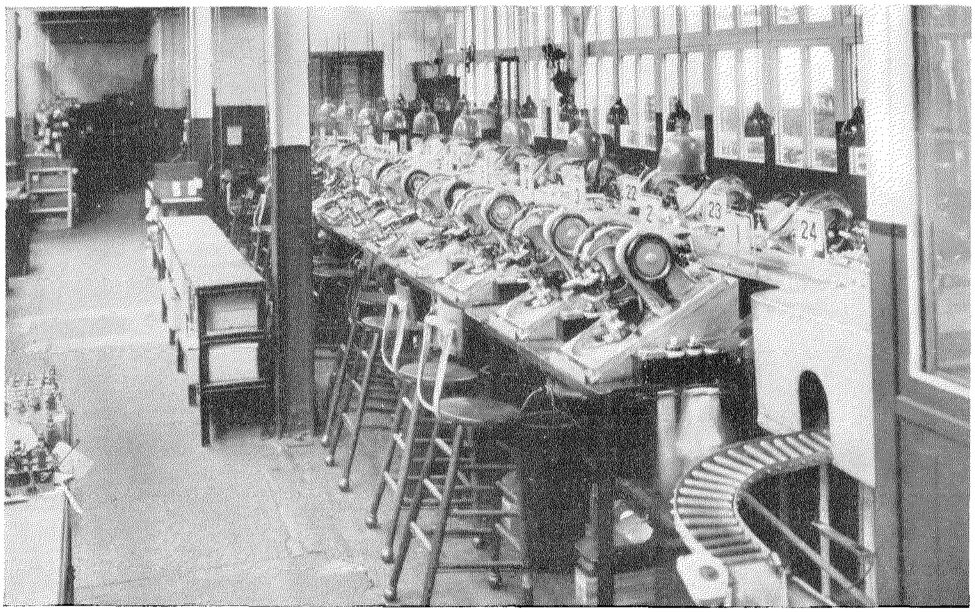

Figure 12—Coil Winding Room.

remembered that the factory deals with the product in vast quantities and the testing must be carried out with sufficient rapidity to maintain the output and with only sufficient accuracy to maintain a consistent quality by the rejection of abnormalities.

Furthermore, there should be sufficient latitude to allow for process modifications without the breaking of any stipulated limit. As an example, take the question of inductance balance between the two lines of the side circuit of a unit and between the two arms of the phantom circuit of a unit. The respective maximum limits for the two circuits are 0.1 percent and 0.25 percent of the total aiding inductance of the circuit under test. It would not be very difficult from the manufacturing standpoint to reduce those two values by a half in each instance, but it is found that such a reduction affects the crosstalk adjustment to the extent of increasing the crosstalk values by an amount sufficient to be apparent in the average crosstalk of all the circuits in the case but insufficient to come within appreciable distance of the maximum limit.

The two values already quoted for unbalance maxima are such as to leave an ample margin as regards system requirements whilst any reduction in crosstalk is always a desirable feature, and it is evident that by permitting factory latitude on the unbalance there has been a resultant improvement in one of the most important features.

From the foregoing it will be seen that the most suitable guarantees are those which will enable the system requirements to be met with sufficient latitude to permit facility in factory testing and slight engineering or factory modifications, at the same time giving due regard to those features which have a direct bearing on the transmission results.

In dealing below with each individual item which forms the subject of a guarantee for loading units, comments are made both on the transmission aspect and method of attaining the stipulated value. The values quoted are intended to apply at a nominal temperature of 15° C.

(a) *Inductance.*

The inductance of any circuit will not deviate by more than ± 1½% from the nominal value when measured at one frequency, either 800 p.p.s. or 1,800 p.p.s., with a current of 1 milliampere.

It is, of course, desirable from the attenuation standpoint to maintain the inductance standard as close as possible to the International standard unit, but it is still more desirable to maintain the inductance of the coils as uniform as possible throughout a repeater section, in order to avoid impedance irregularities in the line.

The magnitude which the manufacture of coils has reached is such as would necessitate the maintenance of sub-standards to a prohibitive degree were any attempt made to work to an International standard unit having laboratory accuracy. Furthermore, any practical advantage accruing from such a practice would be appreciable only in the event of coils manufactured in separate non-co-operative factories being installed on the same repeater section, an occurrence rare enough to be neglected. However, even if it were the case, the effect upon attenuation due to departure from standard would be limited to the effect of the difference between the square roots of the two inductance values and not to the direct values.

The method of controlling accuracy in the factory is to have factory standards which are referred periodically to an International standard and daily to the factory sub-standards; this method has been found to be reasonably accurate in practice, especially since careful watch is kept on corrections for temperature. Uniformity is obtained by a highly developed technique which controls the inductance at all stages of manufacture, the manufactured product always lying well within the guaranteed tolerance.

(b) *Inductance Balance.*

The difference of inductance between the two lines of a side circuit of a unit will not exceed 0.1% of the inductance of the complete circuit. Similarly, the difference of inductance between the two arms of the phantom circuit of a unit will not exceed 0.25% of the inductance of the complete circuit. The tests are made at the same time as the inductance and for convenience are carried out at the same frequency.

The effect of loading coil inductance unbalance on the system is to render it susceptible to interference from sources external to the system.

The values quoted above as maxima are considerably less than the limits which would prove undesirable in practice, whilst the values actually obtained as averages for the coils are approximately half those given as guarantees.

The balance is obtained in the factory by care in winding and by manipulation. Reference has

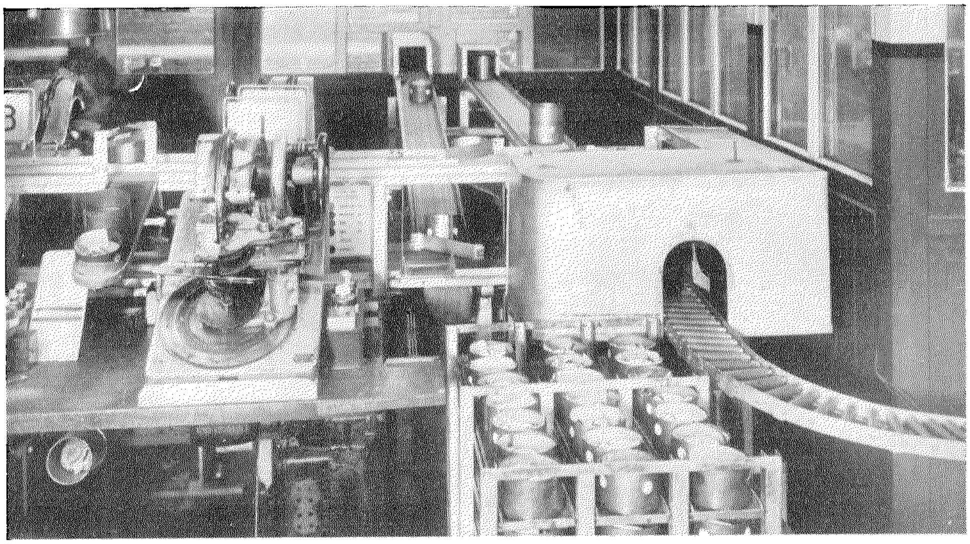

Figure 13—Coil Winding Machines and Belt Conveyor.

already been made to the reaction of inductance balance upon the crosstalk adjustments. The lay-out of a factory coil balancing room is shown in Figure 14.

(c) *Resistance.*

The values of resistance under the conditions indicated will not exceed the values given in the following table:

MEDIUM-HEAVY UNIT 177/63 MILLIHENRYS

	Side Circuit	Phantom Circuit
Maximum Direct Current Resistance	11.4 ohms	5.7 ohms
Maximum Effective Resistance at 800 p.p.s. and 1 milliampere	15.0 ohms	6.5 ohms
Maximum Effective Resistance at 1800 p.p.s. and 1 milliampere	20.5 ohms	8.0 ohms

(NB. On comparing the above figures with average values already shown graphically, it should be noted that the latter do not include any allowance for auxiliary wiring in the case.)

The values given above are defined by the attenuation permitted in the system and are secured in the fundamental design of the unit, as described at the beginning of this paper. Since the values depend upon the dimensions of the coils and upon the characteristics of the core material, abnormalities can only occur through the development of a distinctive fault and the factory control is one of rejection.

By quoting the direct current resistance maximum together with two maxima of effective resistance at two separate frequencies, the degree of attenuation is defined together with an approximate definition of the maximum variation of effective resistance with frequency, a factor which should be kept small in order to avoid frequency distortion in the loaded line.

The factory tests for direct current resistance and for effective resistance at one frequency are carried out on every circuit together with occasional tests at the other frequency. The frequency chosen for testing every circuit is that which is stipulated for the inductance measurement since the two tests are carried out at the same time. Complete tests at the other frequency are unnecessary since any fault which causes an effective resistance reading to exceed the maximum does so by a large margin and leaves no doubt as to the inability to fulfill tests at the other frequencies.

The frequency of 1,800 p.p.s. is preferable to a lower frequency owing to the fact that the higher pitched tone enables the operator to adjust the measuring set to a null point with greater accuracy and rapidity.

(d) *Direct Current Resistance Balance.*

The difference of direct current resistance between the two lines of a side circuit of a unit will not exceed 0.1 ohm.

The difference of direct current resistance between the two arms of the phantom circuit of a unit will not exceed 0.2 ohm.

The effect of the direct current resistance unbalance upon a line is to increase the phantom to side crosstalk.

The values guaranteed above are such as will give complete confidence regarding the crosstalk contributed by this source and there is no reason to decrease the tolerance.

The balance is obtained by careful winding and manipulation.

(e) *Magnetic Stability.*

If any one of the four lines in a loading unit (connected as under operating conditions) is traversed by any value of direct current between 0 and 2 amperes causing magnetisation, the inductance values of the sides or of the phantom circuit will not have changed by more than ± 1% from their initial values when the inductance is measured 5 minutes after the cessation of the magnetising current.

The question of magnetic stability has been discussed earlier in this paper but there is one point in connection with the definition of a guarantee which is worthy of note. It has been found that the degree of inductance deviation as measured five minutes after the magnetic shock varies in accordance with the speed at which the magnetising current builds up or decays. Since the variation may be as much as 0.3% of the total inductance it is desirable to carry out the test with a quick acting snap switch thereby providing conditions which may be repeated with a reasonable degree of uniformity.

For the above reason it is undesirable to give a guaranteed tolerance which is so close to the actual value measured that the above discrepancy may introduce controversy. Another reason favouring a desirable margin is that there is a relationship between the magnetic stability and iron losses whereby a rigid intolerance on one might constrain development on the other.

(f) *Insulation Resistance.*

The insulation resistance between the windings and between each line winding and all other line windings connected to the containing case will not be less than 10,000 megohms when tested with a direct potential of 300 volts.

The value stipulated above is that which enables the fulfillment of the overall insulation tests on the loaded cable.

The required degree of insulation is secured in the factory by careful heating and drying treatment and sealing processes. The temperature and associated humidity conditions prevailing in the factory during manufacture and during the making of the test have an important bearing upon the results.

In one factory situated in a humid region an air conditioning plant has been installed and the results are highly satisfactory.

(g) *Crosstalk.*

The crosstalk expressed in Népers or units of crosstalk measured between the circuits indicated below with an alternating current of from 8 to 10 milliamperes at a frequency of 800 p.p.s., will not be worse than the following values:

WITHIN THE LOADING UNIT

	Side to Side		Phantom to Side	
	Népers	Units of Crosstalk	Népers	Units of Crosstalk
Worst Value	10.4	30	9.5	75
Worst Average per Case	11.1	15	10.3	35

BETWEEN CIRCUITS IN DIFFERENT UNITS

	Pair to Pair		Phantom to Pair		Phantom to Phantom	
	Népers	Units of Crosstalk	Népers	Units of Crosstalk	Népers	Units of Crosstalk
Worst Value	10.4	30	9.9	50	9.9	50
Worst Average per Case	11.1	15	10.8	20	10.8	20

In making the above tests the circuits are terminated with non-inductive resistances having values chosen so as to simulate operating conditions. The above figures apply both to near-end and far-end crosstalk measurements.

From the systems aspect it is desirable to keep the crosstalk always as low as possible with an ideal condition of Zero; there is, however, a practical limit lower than which it is not absolutely essential to proceed. This practical limit is set by the value of crosstalk contributed by the cable itself, and the limits quoted as maxima are those which not only fulfil the latter requirement but also permit further reduction on the part of the cable.

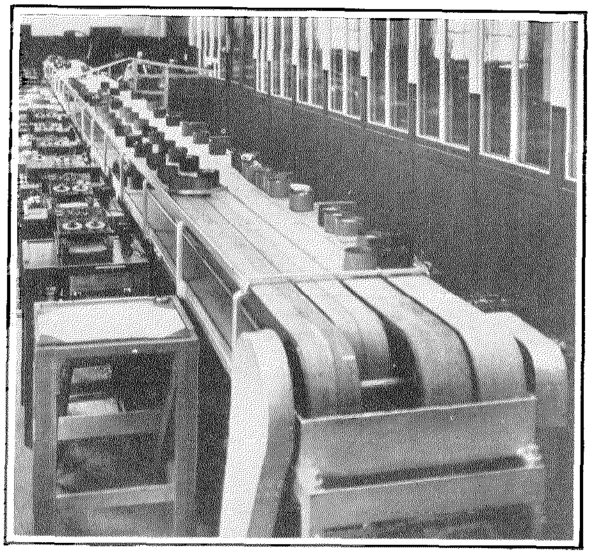

Figure 14—Coil Balancing Room.

It may be of interest to observe that neglecting attenuation the crosstalk on a line is proportional to the square root of the sum of the squares of the crosstalk values contributed by the component parts.

(h) *Breakdown.*

The dielectric between all the windings together and the containing case will withstand an alternating potential of 2,000 volts (R.M.S. value) at a frequency of 25 p.p.s., applied for 2 minutes.

The dielectric between each winding and all other windings connected to the containing case will withstand an alternating potential of 500 volts at a frequency of 25 p.p.s., applied for 1 minute.

As in the case of insulation resistance, the dielectric strength is defined by the breakdown requirements in the line and the above values are representative of equipment for a normal cable. In certain instances such as when the cases are to be installed alongside an electrified railway it may be necessary to increase the limit for breakdown between windings.

The required objective is obtained in the factory by the choice of insulating materials and the degree of separation between conductors. There is no doubt about the above values being met with a wide margin.

It is not claimed that the guarantees given above are sufficient to define the unit as such, but it is believed that the information given is sufficient to cover the functions of the unit in the complete system. Thus, if loading units are to be supplied as a distinct item and without reference to systems guarantees, it may be desirable for the user to supplement the foregoing requirements with others which are peculiar to the project under consideration, and it is certainly helpful for the supplier of the coils to be informed of the general characteristics of the system in which they are to be employed.

Having now given an outline of the properties of the standardised unit for the loading of long distance cables, it is of interest to turn to the types of loading which are auxiliary to or specialised forms of a main long distance cable system.

Loading Coils for Exchange Area Cables

The loading of exchange area cables in Europe has not received the same amount of attention as the loading of long-distance cables and, apart from Great Britain, it has been practically neglected. There is, however, every indication that its use will become widespread and suitable coils have been developed with that end in view.

The general economic requirements for such coils have already been outlined in connection with the description of the evolution of the long-distance coils and those requirements still hold at the present time; that is to say, cheapness and size still override any question of transmission quality, or perhaps it would be more correct to say that the requirements of the system are in no way comparable in magnitude with the problem of cheapness and volume.

It is not within the scope of this article to go into the details connected with the transmission requirements for exchange-area cables but it may be noted that the permissible losses are defined by local factors and the circuit should have a standard of quality sufficient to enable its inclusion in the ultimate portion of a long-distance circuit without impairing the quality of the complete circuit.

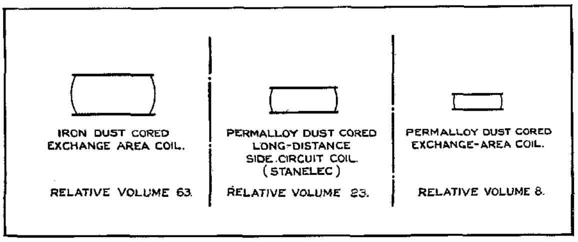
IRON DUST CORED EXCHANGE AREA COIL.
RELATIVE VOLUME 63.
PERMALLOY DUST CORED LONG-DISTANCE SIDE CIRCUIT COIL. (STANELEC)
RELATIVE VOLUME 23.
PERMALLOY DUST CORED EXCHANGE-AREA COIL.
RELATIVE VOLUME 8.

Figure 15—Comparative Sizes of Iron Dust and Permalloy Dust Cored Exchange-area Loading Coils.

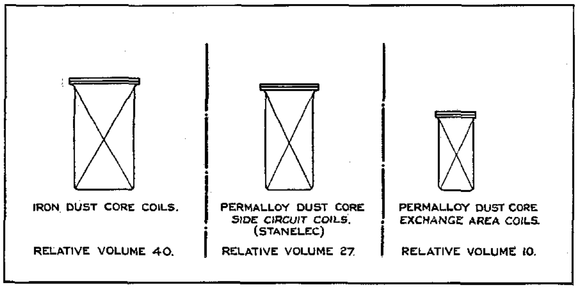
IRON DUST CORE COILS.
RELATIVE VOLUME 40.
PERMALLOY DUST CORE SIDE CIRCUIT COILS. (STANELEC)
RELATIVE VOLUME 27.
PERMALLOY DUST CORE EXCHANGE AREA COILS.
RELATIVE VOLUME 10.

Figure 16—Comparative Sizes of Equipment for Encasing 220 Coils of the Iron Dust and Permalloy Dust Cored Types for Exchange-area Loading.

The type of cable generally used together with the most suitable spacing (2,740 metres) indicate that the loading coil inductance should be 88 millihenrys and this value has therefore been standardised for normal exchange-area loading.

The design of the core for exchange-area coils has been focused entirely on the 88 millihenry inductance value although the question of economically applying the core to coils having other inductance values has not been overlooked.

As in 1925 it has again been decided to use core material identical with that used for the long-distance coil cores, a decision strengthened by the intention to concentrate on the production of a coil having very small dimensions, thus creating only a very small demand for core material compared with the demand for material to be used for long-distance coil cores.

The problems associated with the construction of very small coils have already been discussed. It will be recalled that with the present winding machines the dimensions of the coil having interleaved windings are already a minimum and the only constructional advantage accruing on the exchange-area coil is the permissibility of simple, non-interleaved windings. Fortunately it has been found possible to modify the type of machine used for winding toroidal repeating coils, and the coil resulting from the application of this machine and from a design concentrated on reduced dimensions has a volume which is one-third that of the permalloy dust cored side circuit coil and approximately one-eighth that of the iron dust cored exchange area coil. The relative dimensions of the coils and cases are shown in Figures 15 and 16, respectively, the Stanelec side circuit coil being of interest not only from the development standpoint but also because it has been used to some extent for exchange-area loading during the transitional period elapsing between the completion of the Stanelec coil and the inception of the small coil under consideration.

With regard to the electrical characteristics, provided that the crosstalk requirements are limited to pair-to-pair crosstalk it may be said that the only features in which the exchange-area loading coil differs from the Stanelec side circuit coil are the increased resistance, the diminished accuracy of inductance and resistance balance, and the susceptibility to superposed currents or wide fluctuations in the operating currents.

The increased resistance, while precluding the use of the coil on long distance circuits, in no way approaches the maximum value set by the limitations of circuit attenuation. Assuming therefore that circuit requirements remain static there would be no objection to a further reduction in dimensions but the present limit is the practical one for constructional manipulation.

The graph in Figure 17 shows the resistance characteristics of the three types of coil involved. The reader is referred back to the details regarding the reaction of the iron dust cored exchange-area coil upon long-distance loading coils, a reaction which has been studied in connection with the present situation and which indicates that a coil having the dimensions of the new exchange-area coil is unsuitable for long-distance circuits unless radical developments occur in core material.

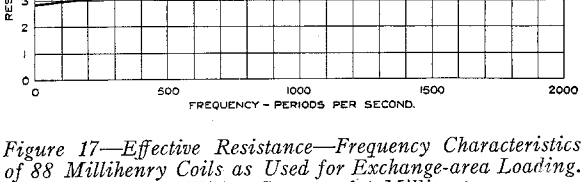

Figure 17—Effective Resistance—Frequency Characteristics of 88 Millihenry Coils as Used for Exchange-area Loading. Measured With a Current of 1 Milliampere.

It is not believed that any useful purpose would be served by enumerating guaranteed values and it is sufficient to state that the only essential clauses in such a specification are those defining inductance tolerance, inductance balance, direct current resistance balance, pair-to-pair crosstalk, and stability to magnetic shock.

Compared with the requirements for Stanelec side circuit coils, the exchange-area coils may normally be permitted twice the inductance tolerance, twice the inductance unbalance, twice the direct current resistance unbalance and an increase of approximately fifty percent on the pair-to-pair crosstalk. Since the same core material is used in both types of coil the stability to magnetic shock is practically the same.

Turning now to coils with inductance values other than 88 millihenrys, those with lower values would be on exactly the same core whilst those with higher inductance values require a larger core, the reason for the latter being that the gauge of wire used for the 88 millihenry coil is so small that any further reduction in diameter would introduce winding difficulties due to breakage of the wire. The core has therefore been increased in volume by increasing the axial height without altering the diameter so that the coil can be encased in the same cases as those used for the 88 millihenry coils, an obvious economy, the difference being that it is possible to stack vertically only 4 of the higher inductance coils as against 5 of the 88 millihenry coils.

Loading Coils for Music Transmission Circuits

As a result of radio broadcast developments it has become necessary to provide cable circuits capable of serving as links in networks used for distributing programmes between the source and the various radio stations participating in the broadcast. The extent of such networks is not limited to the area enclosed by a studio and its attendant national transmitting stations but also covers broadcasts of an international character.

It is obvious that the normal speech transmitting circuits will not fulfil the quality requirements since their frequency band covers a range only of from 300 to 2,500 p.p.s., whilst the frequency band required by the broadcast service is from 30 to 10,000 p.p.s., with particular reference to the low frequency part of the spectrum.

For economic reasons it is desirable to retain the normal loading spacing, and the inductance values for the standardised coils have been chosen so as to give a frequency cut-off of 10,000 p.p.s., with the standard spacing of 1,830 metres. Two types of circuit are in common use, one a pair circuit with 15.5 millihenry pair circuit coils and the other a phantom circuit with 9.0 millihenry phantom circuit coils. In the case of the latter, the side circuits are not used during the period of broadcast transmission and they may or may not be loaded according to the purpose for which they are required.

From the standpoint of loading coil engineering the present transmission requirements on the coils present no difficulties since no attempt is made to attain a highly economical circuit. The attenuation losses which govern the coil resistance are overcome by an increased degree of amplification on the repeaters, whilst the small number of turns of wire required to give the small inductance value mitigates the effects of the increased current due to that amplification.

It has not, therefore, been considered necessary to depart from the standardised type of permalloy dust core as used for the Stanelec speech frequency coils, a course which has been supported by practical results.

Although the manufacture of such coils presents no difficulties, the question of factory testing is another matter since the extension of the test frequency range from that normally used, 1,800 p.p.s., to 10,000 p.p.s., is not only costly but also takes up a period of time incompatible with the importance of the coil under test.

It is not sufficient to modify laboratory equipment to an extent which would suit it to factory testing because the modification would probably introduce errors of an order of magnitude equal to the degree of deviation of a normal factory product.

In view of the foregoing, the factory testing is limited to the tests applied to coils used purely for speech frequency work, random samples being periodically tested in the laboratory. Experiments have shown that it is extremely unlikely that any fault could occur which although apparent at the higher frequencies would remain undetected by the usual tests. Thus a short-circuiting turn would be shown at once by a reduced inductance and increased effective resistance, whilst unusual core permeability would be indicated by an abnormal direct current resistance brought about by the number of turns required to obtain the given inductance.

Probably the only factor which could influence the higher frequency results and not be apparent at the lower frequencies would be an abnormal capacity between coil windings but this deviation could only be due to badly distributed windings which would show up as an increased direct current resistance due to the increased number of turns required by uneven distribution. It may therefore be safely assumed that with accurate testing at the lower frequencies there will be no misplacement of faith in the results at the higher frequencies.

Figures 18, 19, 20, and 21, show effective resistance and inductance versus frequency characteristics for a 15.5 millihenry pair circuit coil and a 9.0 millihenry phantom circuit coil with which are associated two Stanelec 177 millihenry

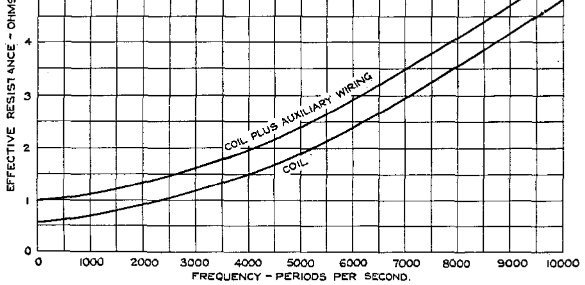

Figure 18—Effective Resistance—Frequency Characteristic of a 15.5 Millihenry Coil for Loading a Music Transmission Circuit. Measured With a Current of 1 Milliampere.

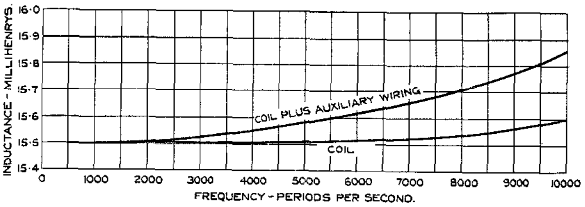

Figure 19—Inductance—Frequency Characteristic of a 15.5 Millihenry Coil for Loading a Music Transmission Circuit. Measured With a Current of 1 Milliampere.

side circuit coils. It will be seen that two curves are shown on each graph, one for the isolated coil or unit and one when it is connected with the auxiliary wiring required between the coil terminal wires and the point at which the main cable joint is made.

The measurements up to a frequency of 2,000 p.p.s., were made on the impedance type of bridge and above that frequency by the series resonance method.

It will be seen that so far as resistance is concerned, the parallelism of the two curves shows that the effect of the auxiliary wiring is simply one of adding direct current resistance. In this connection it should be noted that at a frequency of 800 p.p.s., approximately 40 percent of the apparent time constant $\frac{(R)}{(L)}$ of the encased 15.5 millihenry coil is due to this additional resistance whilst in the case of the 9.0 millihenry phantom unit 7 percent is due to the auxiliary wiring and 75 percent to the direct current resistance of the 177 millihenry side circuit coils.

The above point should be borne in mind when using the time factor as a criterion of coil quality since it is customary to quote only the values measured at the ends of the auxiliary wiring conductors, these being the only points in the circuit which are accessible after the coil is encased.

Although the $\frac{R}{L}$ values for the above reasons may appear to be very large, the actual effect on the attenuation is small, because the resistance added by the loading equipment is still very small in comparison with the line resistance.

With regard to the measured inductance versus frequency curves, the condition is more complex; it will be seen that for the coil alone the inductance is effectively constant at all frequencies but, on adding the auxiliary wiring, there is an apparent increase commencing at a frequency of about 2,500 p.p.s. This increase is apparent in so far as it is neither the true inductance nor the inductance which is effective in the loaded circuit; the cause is the added capacity of the auxiliary wiring.

The capacity between the coil windings is of the order of 1,500 micromicrofarads but owing to the fact that it is distributed it does not tend to cause resonance. The capacity of the auxiliary wiring, however, although only approximately 100 micromicrofarads, is concentrated at the coils ends and has a very pronounced effect at the higher frequencies. In the normal method of testing and the one adopted for the measurements resulting in the graphs under discussion, the test set is connected directly on to one set of coil conductors whilst the other set of conductors is short circuited, the combination therefore being that of an inductance shunted by a condenser. Three effects may occur: the condenser may shunt some of the current which would otherwise flow through the coil, the re-

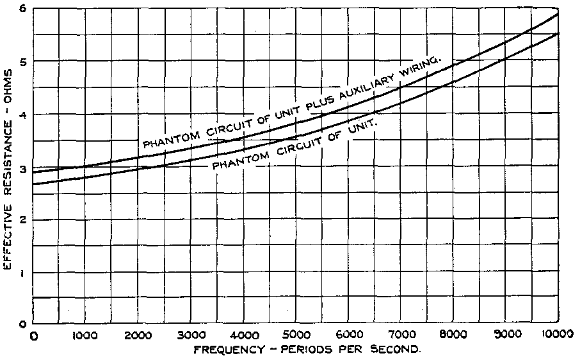

Figure 20—Effective Resistance—Frequency Characteristic of a 9.0 Millihenry Phantom Circuit Associated With Two 177 Millihenry Side Circuit Coils to Form a Unit. Measured With a Current of 1 Milliampere.

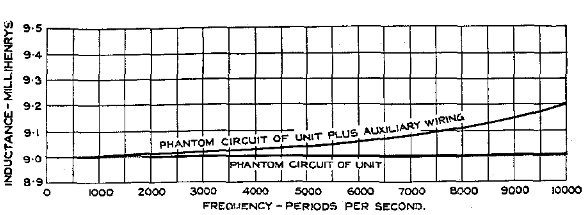

Figure 21—Inductance—Frequency Characteristic of a 9.0 Millihenry Phantom Circuit Associated With Two 177 Millihenry Side Circuit Coils to Form a Unit. Measured With a Current of 1 Milliampere.

duction of current through the latter tending to reduce the effective inductance; the effective permeability of the core material may tend to become smaller as the frequency is increased, again reducing the inductance; finally, the circuit may tend towards resonance, thereby producing an apparent increase in inductance. The two former effects are slight in any coil and particularly so in a coil of low inductance value, but the resonance effect as indicated by the curves is a conspicuous feature.

So far as the loading of the line is concerned the increase in apparent inductance of a coil under test conditions may be neglected, since it is the true inductance which is effective and not the unreal inductance brought about by a tendency to resonance.

If it were desirable to derive the true inductance from the bridge reading at a high frequency, it could be done by applying mathematical corrections. The fact that the apparent inductance curve and true inductance curve coincide at the lower frequencies shows that such a course is unnecessary, and provides a strong argument for restricting factory testing to those frequencies.

With regard to the permissible inductance tolerance, it is undesirable to work to a value of less than ± 2% of the nominal value owing to the smallness of the latter increasing the effect of turn adjustment.

Apart from inductance, the most important feature is that of crosstalk and immunity in this respect is obtained both by isolation of the coil in the case and the conductors in the auxiliary wiring. It is customary to guarantee that the crosstalk between the music circuit coil and any other coil within the case will not be worse than 12.2 népers (5 units of crosstalk) when measured under the same conditions as those applying to the normal speech frequency equipment.

The Loading of Open-Wire Lines

The loading of open-wire lines was discontinued on the introduction of the repeater. Prior to that event it was carried out in Europe to a very limited extent.

Non-loaded open-wire lines may be constructed to give satisfactory results up to approximately 300 kilometres. Beyond that distance it is more economical to install repeaters than to load the circuit.

It is obviously difficult to obtain a high grade of insulation on open-wire lines. Since loading increases the impedance of the circuit it also increases the irregularities due to the leakage losses, thus rendering it unsuitable for use with repeaters. Another objection is the increased maintenance difficulties brought about by the necessity for protection against damage by lightning.

In view of the foregoing not only is it no longer the practice to load open-wire lines but in some cases the coils have since been removed from lines previously loaded.

The Loading of Carrier Frequency Circuits

It is not proposed in this paper to cover the field of loading coils for carrier frequency circuits since it is impossible to treat the subject as a supplement to voice frequency loading and any attempt in this direction would confuse the distinction between the problems associated with carrier frequency loading and those prevailing on voice-frequency and music frequency loading.

The following notes are therefore intended merely to indicate some of the salient features of the subject.

The carrier frequency portion of the spectrum ranges from 5,000 p.p.s. to 30,000 p.p.s., and the loading is applied only to the toll entrance or intermediate cables and office wiring and not to the open-wire lines. The carrier frequency circuits proper are on the side circuits only whilst the phantom circuits are used for telegraph or voice frequency working; it is, therefore, unnecessary to load the phantom circuits at every point at which the side circuit is loaded and phantom loading is applied at every second, third, or sixth loading point depending on the carrier system in use. The spacing between points is either 284 metres or 914 metres, again depending on the system.

The side circuit coils which are used at the 284 meter spacing have inductance values less than 5 millihenrys which together with the high frequency in use makes it undesirable and unnecessary to use metallic cored coils, first, because the inductance can be obtained with few winding turns and second, because the presence of metal within the inductive field would create losses due to eddy currents.

The phantom circuit coils are of low inductance, of the order of 12 millihenrys, to match the impedance of the open wire line, but the working frequency is low and the normal type of permalloy dust core can be used.

In view of the fact that the nomenclature of carrier loading equipment is similar to but not coincident with voice-frequency loading equipment, the following details may assist in distinguishing the various apparatus involved.

There are four main items of loading equipment, namely, the side circuit coil, the phantom unit, the side circuit terminal unit, and the phantom circuit terminal unit.

As its name implies the side circuit coil is simply one coil and has no associated equipment.

The phantom unit is a combination of two side circuit coils along with one or two coils, according to the system for loading the phantom circuit.

The terminal units are used at the end of the circuit in order to secure a non-reactive impedance characteristic over the frequency range in use. The inductance added by a terminal unit to the circuit with which it is associated is a fixed fractional value of the loading on that circuit; this scheme is known as compensated loading.

The side circuit terminal unit consists of a fractional inductance side circuit coil across which is shunted a retardation coil in series with a condenser. It is used only for compensating the side circuits.

The phantom terminal unit is used for compensating both side and phantom circuits and consists of two fractional inductance side circuit coils, two retardation coils effective only on the side circuits, two fractional inductance coils which load the phantom circuit, two retardation coils effective only on the phantom circuit, and finally, four condensers in mesh formation between the side circuits.

It will be realised from the foregoing that with the small values of inductance and with the high frequencies involved the problems which arise call for an entirely different technique from that associated with voice frequency loading coils.

The use of a non-magnetic core material such as wood or bakelite simplifies the adjustment of inductance at the low inductance values involved but the problems of capacity, capacity unbalance, "skin" effect and eddy current effects inherent in the copper windings are such as to necessitate a high degree of control and manipulation in order to produce an efficient and uniform product.

As may be surmised from the testing problems associated with music circuit coils, the testing of carrier frequency coils requires special apparatus capable of indicating resistance losses of a character quite distinct from those encountered on the voice frequency coils.

In order to reduce interference to a minimum it is necessary to place each coil or unit inside a copper can and all auxiliary wiring must be fully screened.

The use of carrier frequency loading is not yet very widespread but unlike the loading of music circuits for broadcasting purposes there is no factor likely to limit the extent of its use. Although the present demand in Europe is small, it is necessary to keep in view the probability of production in quantity, thereby involving a slow advance in the preliminary stages of manufacture.

Special Voice Frequency Loading Coils

The foregoing description of permalloy dust cored coils has been confined to a type designed with a view to its association in the economic unity of the system. If, however, the economic question is neglected and the designer is confronted only by electrical requirements, then the permalloy dust core material is conspicuous by the ease with which it is possible to produce coils unique in their low values of resistance and yet retaining dimensions capable of manipulation.

This increased flexibility in design has made it possible to supply coils for operation on special systems and of a size such as will not disturb existing installation facilities.

Future Possibilities

In concluding this portion of the paper which so far has been confined almost entirely to the coils themselves, it will not be out of place to discuss briefly the possibility of future changes.

It is believed that the present product is not only satisfactory from the economic and electrical standpoints but that it covers those features to a degree sufficient to permit modifications in the other components of the systems.

At the present moment, therefore, the effects of any improvement would be experienced mainly by the designers of the coils as a pleasant consciousness of having available some property in excess of normal demands. Such a consciousness is usually short lived since the system engineers rarely fail to discover some significance of the new property which then becomes a specified feature.

Probably the most fruitful improvement which could occur would be the production of a coil capable of rigidly maintaining its initial inductance and resistance values despite the passage of large operating or superposed currents in the windings.

Another desirable advance would be the association of the above properties with a coil wound on a core of higher permeability, thus enabling either the resistance or the dimensions to be still further reduced. Any changes in the latter direction would, however, almost certainly involve either a new method of winding or a complete change in the construction of the coil.

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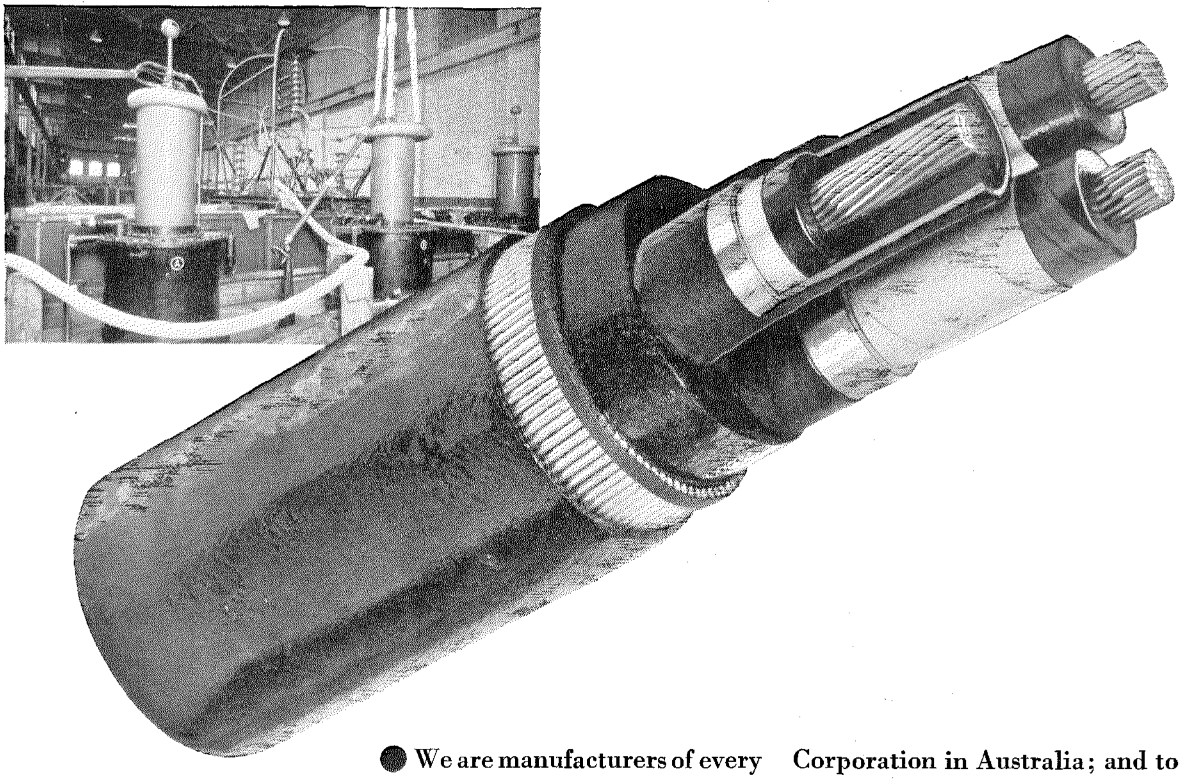

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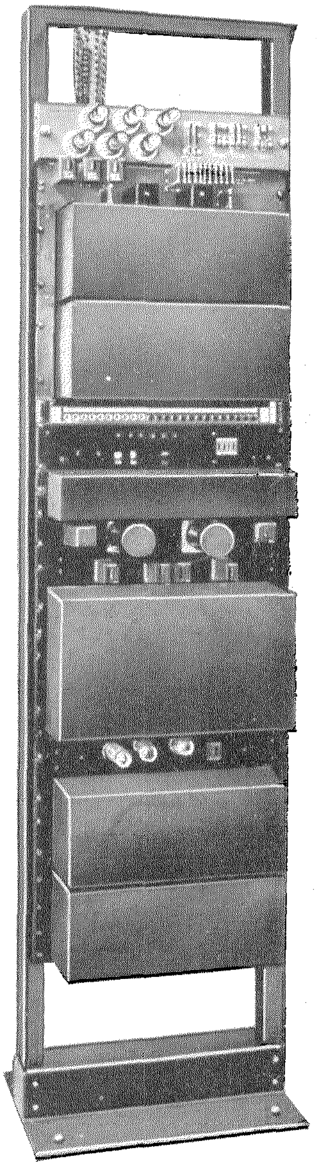

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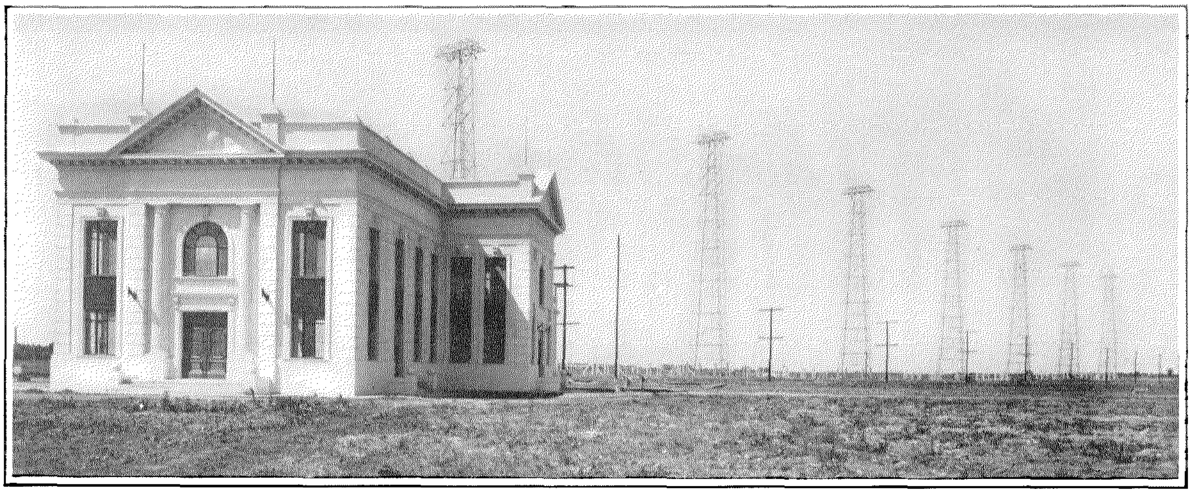

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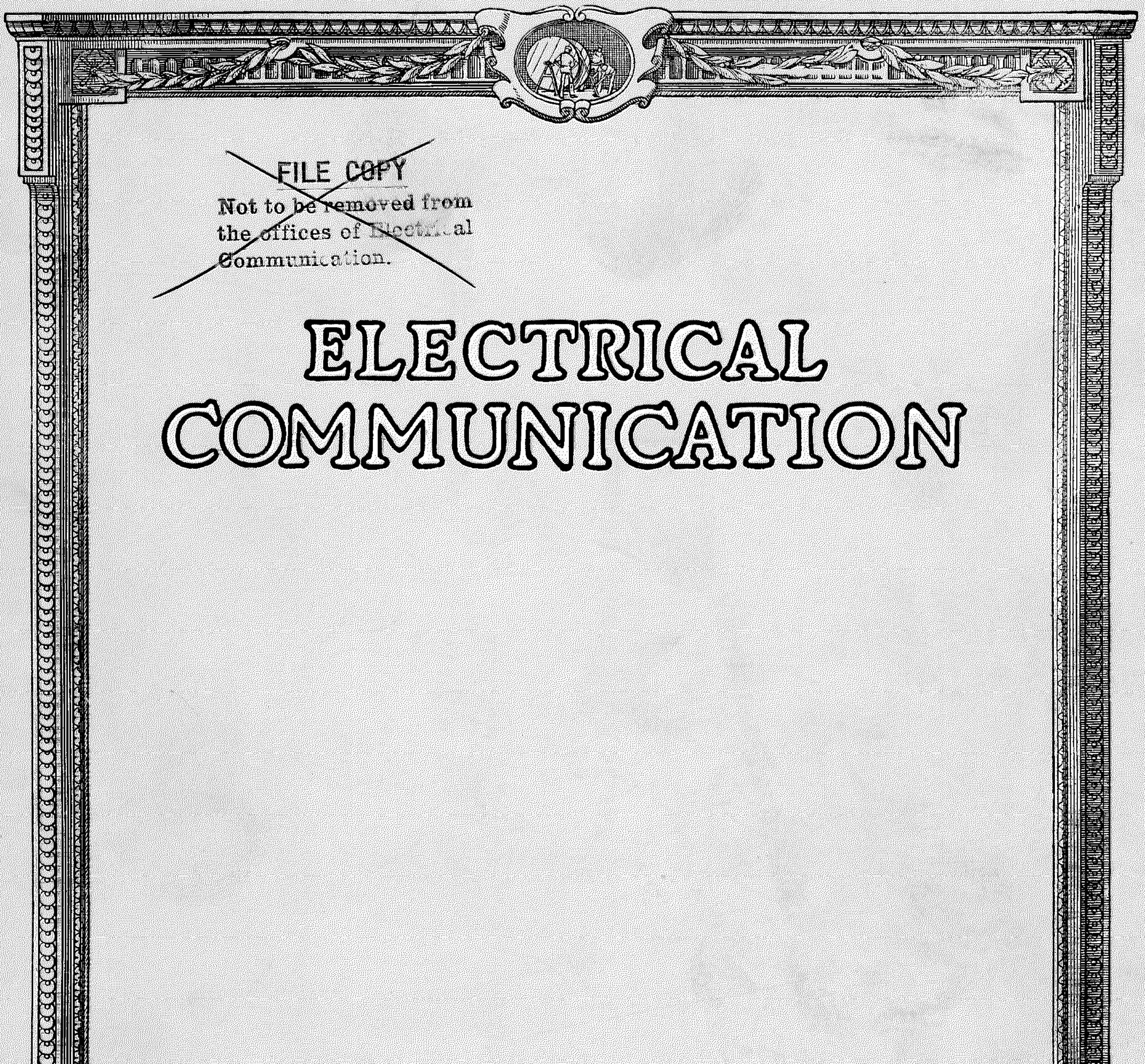

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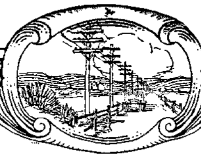

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CONTENTS

PAGE

TELEPHONE PROBLEMS AND PROGRESS IN RUMANIA........ 175
By G. A. Ogilvie and Bruce H. McCurdy

A NEW VOICE FREQUENCY TELEGRAPH SYSTEM........... 184
By J. A. H. Lloyd, W. N. Roseway, V. J. Terry and A. W. Montgomery

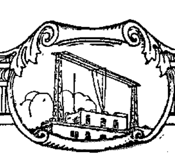
AN AUTOMATIC CONCENTRATION UNIT FOR PRINTING TELEGRAPH CIRCUITS.................................... 200
By G. S. Vernam

DIRECT PRINTING OVER LONG NON-LOADED SUBMARINE TELEGRAPH CABLES.................................... 210
By M. H. Woodward and A. F. Connery

BALANCING CABLES BY INDUCTIVE NETWORKS............ 218
By M. I. Pupin

MODERN LOADING EQUIPMENT.......................... 223
By J. B. Kaye

HONGKONG-CANTON TOLL TELEPHONE CABLE............ 237
By P. T. Carey and R. E. Burnett



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Telephone Problems and Progress in Rumania

By G. A. OGILVIE
General Manager, Societatea Anonimă Română de Telefoane
and BRUCE H. McCURDY
Engineer of Toll Lines and Transmission for Rumania

ON January 1st, 1931, the Societatea Anonimă Română de Telefoane, an operating company in the International Telephone and Telegraph group of companies, took over the operation of the telephone network, both local and toll, of Rumania. This network included 1380 exchanges with approximately 52,000 stations and a toll network of over 56,000 circuit kilometers spread over an area of 122,282 square miles (316,700 square kilometers). In general, the plant and equipment taken over was in fairly good condition. However, in the local plant, equipment ranging from the earliest magneto to the latest rotary automatic has been found, while in the toll network it has been necessary to deal with numerous completely different types of construction and with circuit arrangements varying with almost every kilometer. The problem of welding such a network into a unified system and of providing economically the necessary additions to handle the traffic demand over the period of reconstruction has been one of great complexity and unusual interest.

Development of Toll Service

With the exception of Bucarest, where there was a very large unsatisfied local demand for service, the most urgent requirement has been for an amplification and improvement of the toll service, especially that between Rumania and other points in Europe. Fortunately it was in this very field that the greatest amount of immediate relief could be given. This relief took the form of (a) new circuits provided by carrier, (b) new circuits obtained by the phantoming of existing wires, (c) stringing of new copper circuits and (d) the bettering of service by means of transmission cleanups and revision of routings.

a). *Carrier Development.*

Within three months of the taking over of the plant a C-S-3, three-channel Standard Electric carrier system was installed between Bucarest and Timişoara over an existing 4 mm. bronze circuit (Figure 1). A month later a second similar system was installed between Bucarest and Oradea with repeaters at Braşov and Cluj (Figure 1). The terminal points for these first systems were selected with a view to getting as wide a distribution of new high-grade circuits as possible. Individual channels were extended over new or existing voice frequency circuits and as a result it was possible with these two systems to obtain direct circuits from Bucarest of 6 db equivalent to Timişoara, Oradea, Budapest and Vienna, none of which, with the exception of Timişoara had been provided with such direct circuits before.

With the opening of the direct circuits to Budapest and Vienna it was possible to offer to the public international service not only between Rumania and the two capitals involved but also to the majority of the countries in Europe. Some advertising was attempted as soon as the new circuits were put in service but the flood of traffic was such that it had to be discontinued almost immediately and steps taken at once to provide still more facilities for international service. The same proved true in the case of the new and better internal service made possible by these systems.

The provision of more facilities by carrier presented a number of very complex engineering problems. The two systems already installed to the west had utilized the only existing pole line routes suitable for carrier. Although the working of more than one carrier circuit over the same line is quite feasible, there were serious difficulties in the particular case in question since in no case where parallel systems were desired were there available two circuits of the same gauge and characteristics. Extensive tests were made, however, and a system of transposition designed to allow working a single channel system (D-1) between Bucarest and Braşov over the same route utilized by the Oradea system and a second (DA-1) between Bucarest and Szeged (Hungary) over the route of the Timişoara system. These systems were installed in July and August respectively and, as predicted by the preliminary calculations, the voice frequency crosstalk between interfering channels in both cases was less than 600 units (over 7.4 népers). As a commentary on the results possible with such carrier systems it is interesting to note that the Bucarest-Szeged DA-1 system—which forms a part of the direct Bucarest-Budapest circuit—works without an intermediate repeater over a line consisting of 563 km. of 4 mm. plus 109 km. of 3 mm. and 1.3 km. of toll entrance cable, is by-passed at three points and still allows a 3.0 db circuit to be obtained for the carrier portion of the circuit. The normal noise on this circuit is less than 200 units. In fact, the quality (see Figure 2) and stability of this circuit was such that it was selected as the most suitable circuit for use in the recent demonstration between Washington and Bucarest and gave perfect results.

Up to the present Bucarest has been provided with the following new direct international circuit groups, all by means of carrier within the Rumanian territory:

Bucarest-Paris	1
Bucarest-Vienna	1
Bucarest-Budapest	2
Bucarest-Prague	1

A second Bucarest-Vienna and a Bucarest-Berlin circuit are now being provided for by replacing the DA-1 with a three-channel (C-N-3) system between Bucarest and Szeged.

In the case of all of these international circuits the greatest co-operation has been shown by the Hungarian Administration of Posts and Telegraphs, who have provided in their territory open

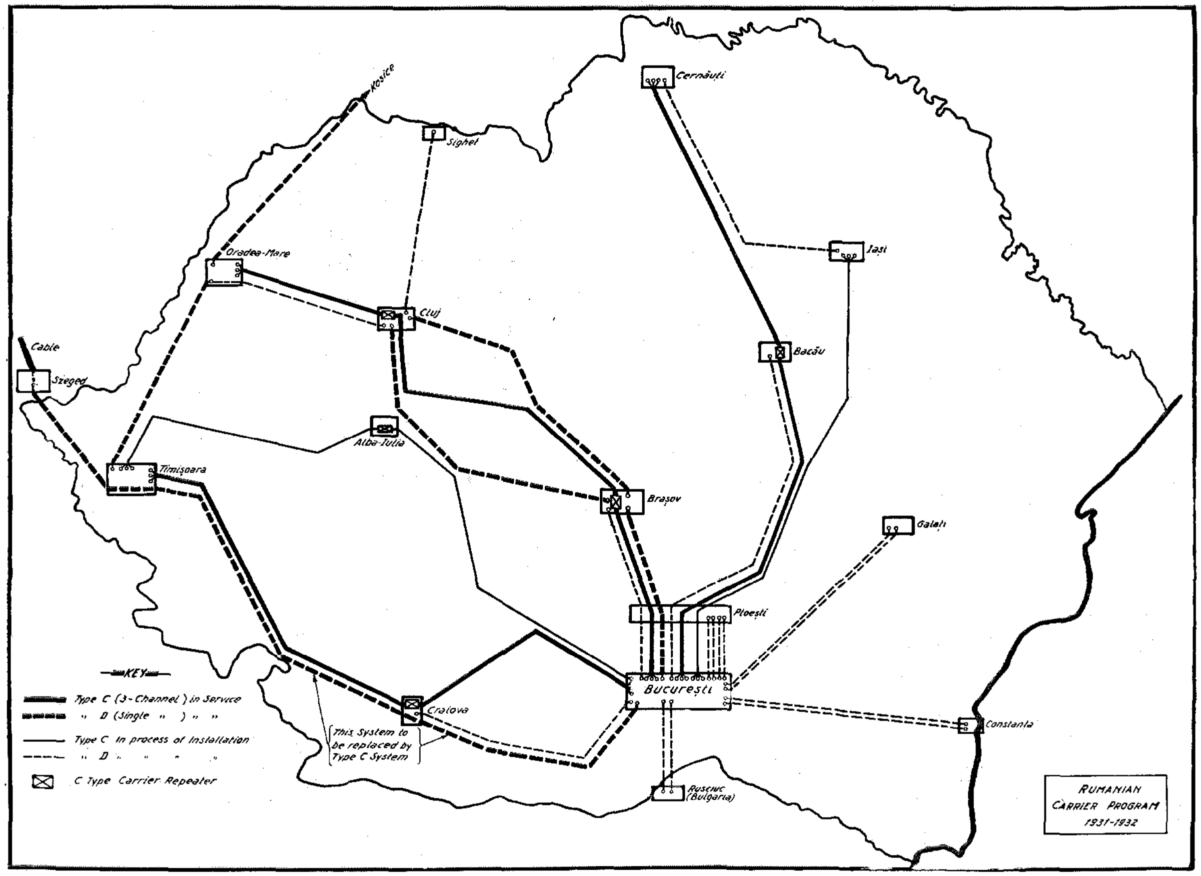


Figure 1—Rumanian Carrier Program, 1931-1932.

wire circuits from the Rumanian frontier to their cable terminals at Szeged and Solgnod as well as cable circuits from these points to Budapest and beyond.

Shortly before the installation of the two type D systems mentioned above, a third three-channel (C-N-3) carrier system was installed between Bucarest and Cernauți. Here again the question of interference had to be solved since between Bucarest and Ploești, a distance of 65 kms., this system utilized the same pole line as the Bucarest-Oradea C-S-3 and the Bucarest-Brasov D-1 systems. As a further complication the Bucarest-Timișoara and the Bucarest-Szeged DA-1 system utilized this same pole lead for the first 15 km. out of Bucarest. By proper segregation and transposition and adjustment of energy levels, however, it has been possible in every case to reduce the voice frequency cross-talk between interfering channels to less than 600 units.

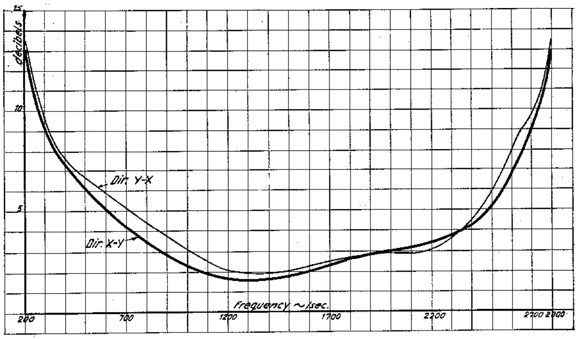


Figure 2—Overall-Loss-Frequency Curve, Bucuresti-Szeged, DA-1 Carrier System.

So successful has carrier proved in Rumania that as soon as it was possible definitely to predict traffic demands, three additional type C three-channel systems and 15 type D and DA single channel systems were placed on order, three of the D systems actually being in service at the time of preparing this paper. The rest are to be installed as indicated in Figure 1. In the majority of instances it has been found possible to install these systems without extensive re-transpositions except where more than one system is to be used on a lead, the only transpositions cut in for the case of single systems on a lead being those necessary to eliminate absorption points (Figure 3). Between Bucarest and Ploești, where there will be a high concentration of both C and D carrier systems, an elaborate system of carrier transposition is being made. In order to obtain the greatest efficiency out of such transpositions the standard International Telephone and Telegraph point transpositions (Figure 4) will be used rather than the rolling transpositions normally employed on voice frequency lines.

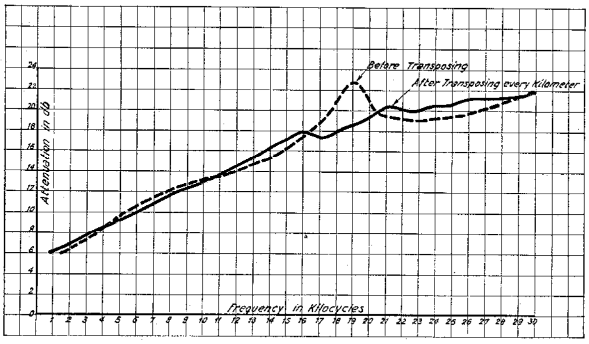


Figure 3—Attenuation-Frequency Curve, Bucuresti-Craiova, 4 Mm. Circuit.

b). *New Phantom Circuits.*

In the toll plant taken over it was found that practically no use had been made of possible phantom facilities. Only one phantom circuit of commercial grade, and this one only approximately 60 km. in length was in operation in January of 1931. It was decided, therefore, in order to meet the requirements for shorter-haul

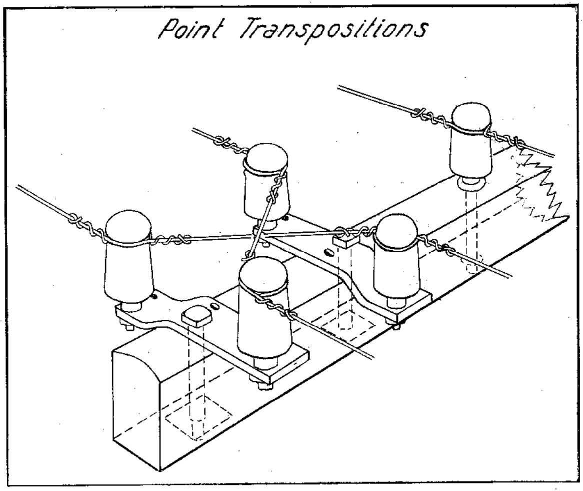


Figure 4—Point Transpositions.

internal traffic to attempt a general program of retransposing existing lines for such phantom operation since in a large number of cases physical lines of sufficiently regular characteristics were found to exist. This work was started early in the spring of 1931 and has resulted in the addition of over 2,700 circuit kilometers to the toll network. Although the individual circuits were in fair condition this retransposing has involved a large amount of very special engineering on the part of the technical force since the variety of construction methods used in the country made it impossible to utilize any known standard system of transpositions, each section of line being a special problem in itself. As illustrative of the difficulties encountered, the case of two phantoms between Oradea and Cluj may be cited. These two phantoms involved some seven or eight types of construction and mounting of circuits, six of which are shown in Figure 5. To further complicate the problem, the type of construction and mounting of the circuits involved varied with almost every kilometer. In spite of this, however, two phantoms were obtained with crosstalk and noise characteristics as follows:

1). Crosstalk	Crosstalk Units	Népers
Side (1) to Side (2)	800	7.12
Side (1) to Phantom (1-2)	1000	6.88
Side (2) to Phantom (1-2)	1200	6.67
Side (3) to Side (4)	600	7.50
Side 3 to Phantom (3-4)	800	7.12
Side 4 to Phantom 3-4	1200	6.67
Phantom (1-2) to Phantom (3-4)	1800	6.30

2). Noise	
Phantom (1-2)	500 units
Phantom (3-4)	500 units

As an experiment, and because additional circuits were still necessary over this route, an attempt was made to build up a "super-phantom" or "ghost" on the two phantoms already obtained with the following results:

1). Crosstalk	Crosstalk Units	Népers
Super-Phantom to Phantom (1-2)	1800	6.30
Super-Phantom to Phantom (3-4)	2000	6.20
Maximum Crosstalk from Super-Phantom to other Circuits on lead	1800	6.30

2). Noise	
Super-Phantom	600 units

The general use of super-phantoms would not of course ever be considered. Even in this case

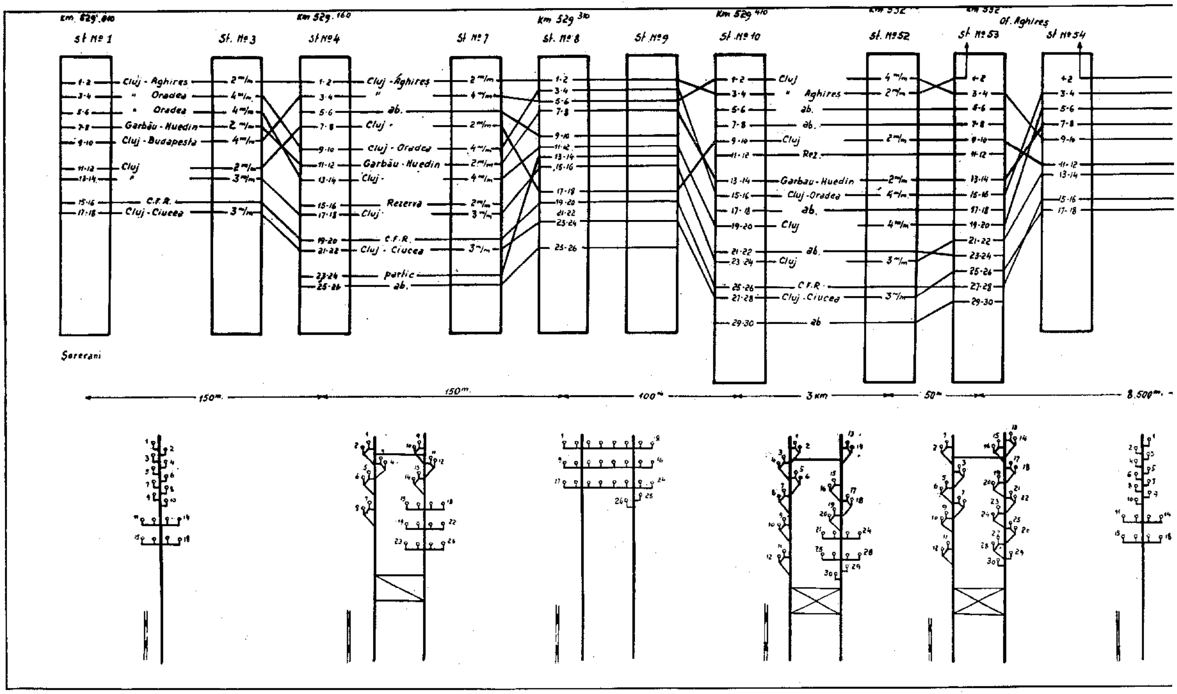


Figure 5—Types of Construction and

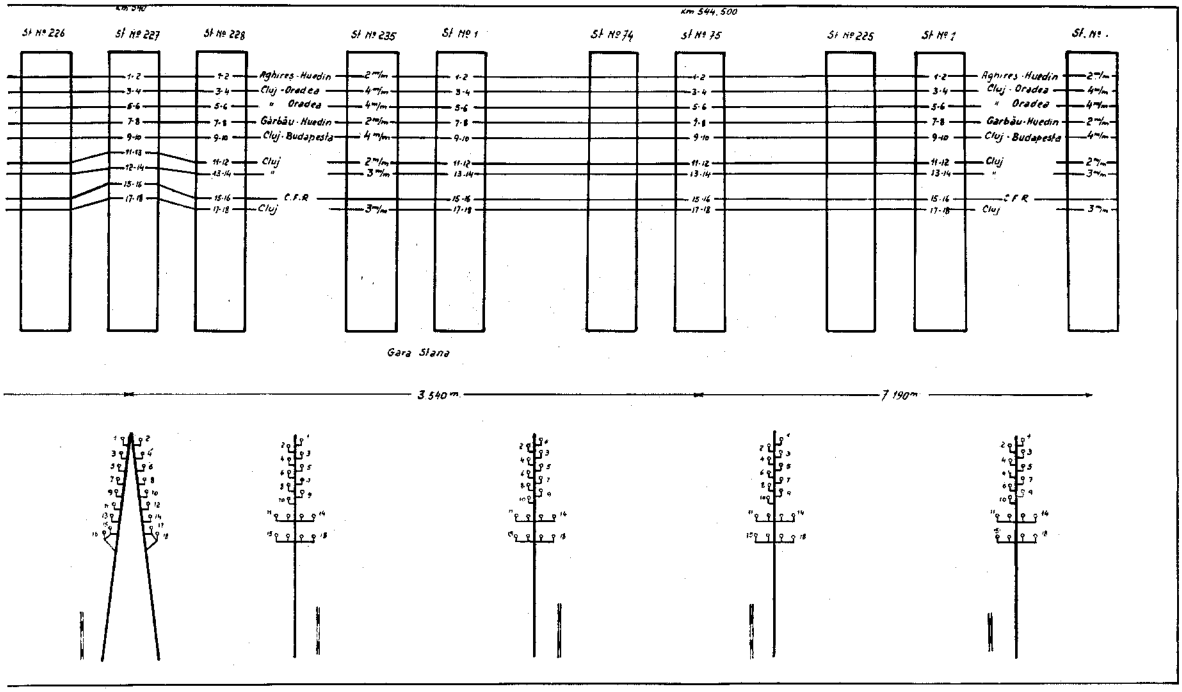
the quality leaves considerable to be desired. This particular super-phantom, however, has proved very satisfactory for terminal connections between Oradea and Cluj and is actually being commercially exploited. All of the regular phantoms put in service in Rumania during 1931 have proved very satisfactory both from the standpoint of quality and dependability and are being used indiscriminately with physical and carrier circuits for both short-haul and long-haul service.

c). *New Copper Circuits.*

Of the 10,000 circuit kilometers added to the Rumanian toll plant in 1931 less than 250 circuit kilometers have required the stringing of new copper. Where new copper has been added it has, in general, been strung on existing types of supports and, wherever possible, it has been coordinated with existing wires to permit phantoming. Such new copper, however, has been kept at a minimum pending detailed studies of future routes and of the condition of the existing pole plant.

d). *Transmission Improvement and Toll Centering.*

In addition to an actual lack of facilities two other hindrances to good toll service were found to exist. In the first place the majority of circuits were found to be low in insulation and to contain high resistance joints, etc., with the result that the actual transmission losses were high and the noise almost generally considerably beyond allowable limits for efficient service. In the second place the arrangement of the circuits was such that effective and efficient toll routings for via business could not be given. By means of an extensive program of transmission measurements to locate faults and to determine actual transmission losses with a subsequent clean-up program on all lines found to be in trouble, a very decided step toward eliminating the first of these hindrances has been made. Simultaneously, and with the aid of the transmission results obtained through this general transmission improvement program, the second of these hindrances has been attacked through the agency of a combined traffic and transmission study which has taken the form of a general toll centering plan similar to that now in force in the United States. In general, this plan consists of providing extra high-grade facilities interconnecting a certain few strategically located concentration centers. These centers are in turn provided with high grade circuits to all toll



Mounting Encountered on Toll Lines.

centers in the areas immediately surrounding them. By coordinating the traffic and transmission factors involved, there is being set up a general switching plan which will allow extending toll service to all points in Rumania with the minimum possible increase in circuit groups and in expenditure for improved transmission on secondary lines which are used primarily for short-haul traffic.

The region around Cluj may be taken as an instance of the operation of the new switching plan. Turda, Dej, Bistriţa and other towns immediately surrounding Cluj (Figure 6) all were found to have potential traffic to Bucarest and beyond, both in Rumania and to points outside of Rumania. Under the arrangement of circuits in existence the first of the year practically none of these points could talk beyond Braşov in the direction of Bucarest or beyond Oradea to the West. Under the new plan all of such points are concentrated at Cluj which in turn is provided with a high grade circuit to Bucarest. The result has been that every one of the above points is now in quick contact with Bucarest at transmission losses well within the permissible transmission range and through Bucarest can be connected to the remainder of the country as well as to the rest of Europe over the international network terminating at Bucarest. All this was accomplished through certain circuit rearrangements which permitted setting up a high grade Bucarest-Cluj circuit and the concentration of the centers at Cluj over circuits of suitable grade. Incidentally, the demand for traffic from these centers has grown to such an extent that it will be necessary to increase the Bucarest-Cluj facilities by adding two circuits before the end of 1932.

The main network of high grade circuits which will be available for 1932 is illustrated in Figure

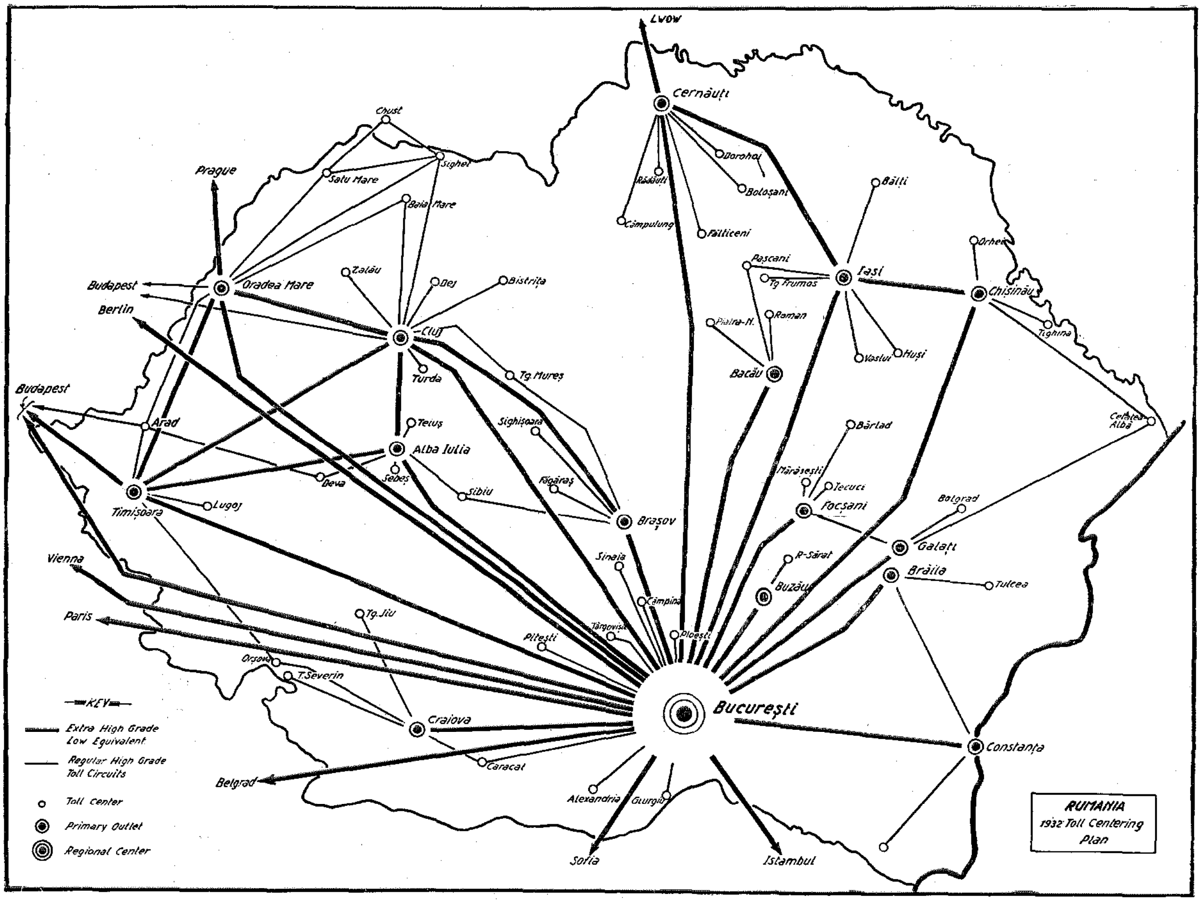


Figure 6—Provisional Toll Centering Plan for 1932.

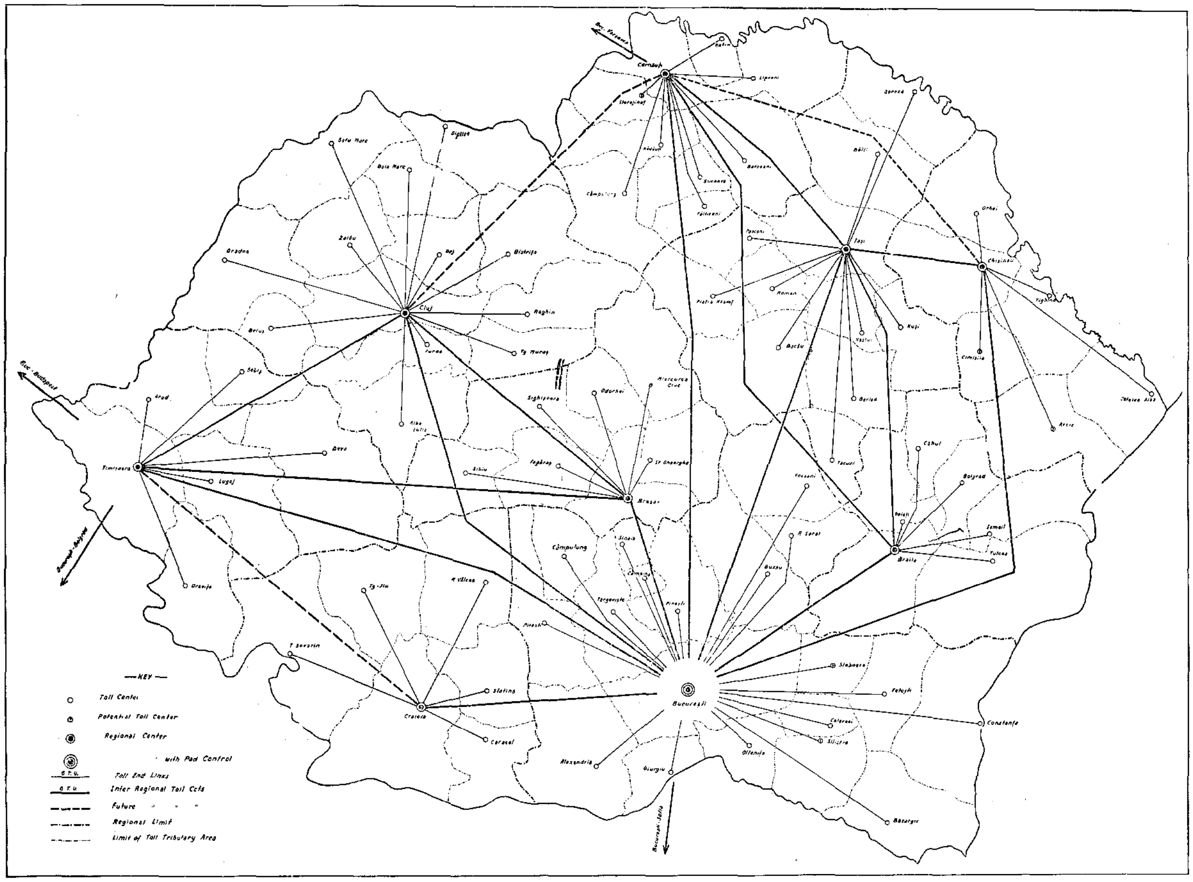


Figure 7—Final Toll Centering Plan for Rumania.

6. This will undergo some modification as new circuits are added and will within a few years be reduced to the final toll centering plan shown in Figure 7. As will be noted the final plan reduces the number of major concentration centers of the type mentioned above from 15 to 9.

Growth of Toll Traffic

By means of the additional facilities mentioned above (i.e., carrier, phantom and new copper) over 10,000 circuit kilometers have been added to the toll network during 1931. Due to the large use of phantoms and carrier this has been accomplished more economically than would have been the case if the circuits had all been provided by new 3 mm. copper. As a result of these additions and the more efficient utilization of existing circuits obtained by the transmission improvement and toll centering programs, the toll traffic has increased at a surprising rate, as will be seen from Figure 8, at a time of increasing economic strain when in almost every other part of the world toll traffic has been decreasing.

Development of Local Service

The existing local plant in Rumania utilizes for the most part, except in Timişoara and Bucarest, open-wire circuits which are carried on poles along the streets or on special roof-top structures of the type shown in Figure 9. Considerable difficulty is being experienced in adding to this open-wire plant due both to the over-loaded condition in which these lines are found and to the objection of having more open-wires hung in the central business areas where the exchanges are usually located. In certain cases, where the demand for new circuits has been especially urgent, it has been found possible and economical to install short sections of aerial or block cable in the central portions of the town. In the

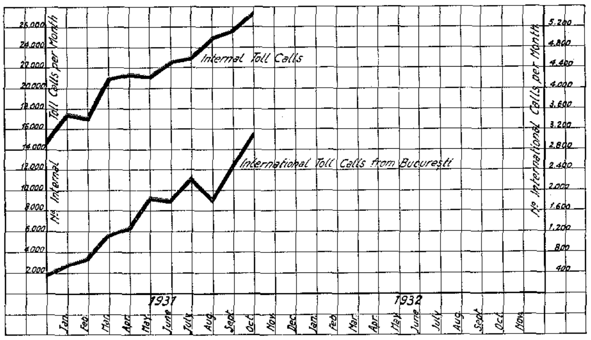


Figure 8—Toll Calls Completed Per Month.

majority of instances, however, immediate relief has had to be confined to such bettering of existing service as could be obtained by clearing the numerous cases of trouble which have been found to exist in both plant and equipment. A very large amount of this type of work has been done with a very marked increase in the grade of service given to the public.

In Bucarest, on the other hand, it has been possible to coordinate additions to both plant and equipment with the plans for the ultimate conversion of all Bucarest to automatic. Twenty-four hundred lines of automatic equipment with its accompanying outside plant have been added to care for new subscribers in the existing automatic area and to allow taking over temporarily a small portion of the existing manual area. The plant and switchboard facilities released in this way were thus made available for additions in the manual area. In Ploeşti, the first city in Rumania to be completely converted, a new rotary automatic exchange is practically ready for cutover.

The problem of converting Bucarest entirely to automatic is presenting a number of very interesting engineering problems, chief among which has been that of determining the most economic arrangement and location of exchanges. Based on detailed commercial studies of expected growth by city blocks, various trial distributions are being engineered using one, two, three, four, and five separate exchanges. These studies are sufficiently well advanced to permit the preparation of more detailed engineering plans for the actual duct work and for a large portion of the initial cable plant. In fact, intensive work on this outside plant is now under full headway and it is expected that by July of 1933 Bucarest will be fully converted to rotary automatic.

A second very interesting feature of these studies has been the consideration of the possible use of 26 gauge (0.4 mm.) cable circuits for a portion of the local distribution. This possibility has arisen as a result of three main factors. In the first place, in the toll fundamental plan for Rumania, a toll distribution of such characteristics is assumed that in the special case of Bucarest "toll terminal losses"[1] as high as 10 db may be allowed. This means that the local plant can be engineered for almost all combinations of gauges up to the extreme limits determined from purely local consideration.

The transmission standards actually met are:

a). Maximum subscriber-to-subscriber loss[2]
    Residential area to residential area . . . . 24 db
    Residential area to business area . . . . 20 db
    Business area to business area . . . . 18 db
b). Maximum toll connection from limiting Bucarest subscriber to limiting subscriber in provinces . . . . 30 db
c). Maximum toll connection from limiting Bucarest subscribers to limiting subscriber in main toll centers of Rumania . . . . 27 db

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[1] The toll terminal loss is defined as the average of the transmission losses, transmitting and receiving, of the circuit from and including the subscriber's station to the toll line jacks at the toll switchboard.

[2] This includes, of course, the battery supply losses.

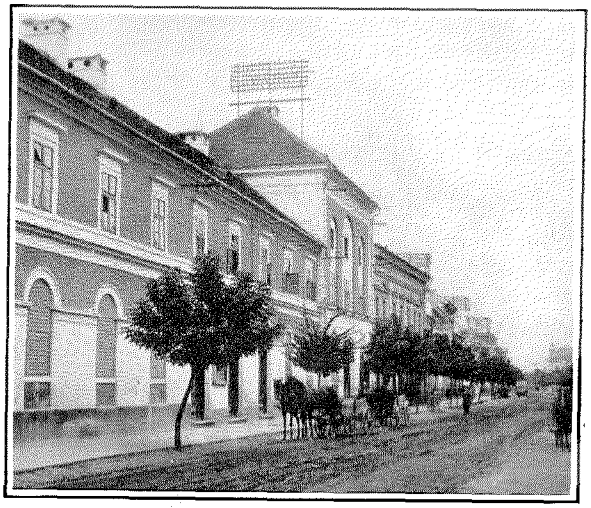

Figure 9—Existing Roof Type Local Distribution.

Underground Conduit Work in Progress in Bucharest.

It should be noted in connection with the above standards that whereas the design standards given are maximum values, actually very few connections will reach as high values of loss as those given in the tabulation. This is well illustrated in Figure 10.

A second factor which has led to a consideration of 26 gauge cable is the high efficiency of the present type Bell Telephone Manufacturing Company subset which will be used throughout Bucarest. Even discounting the increase in "effective transmission" due to the increased articulation and reduction of room noise obtained with the new set, a very material increase in efficiency is accomplished, as compared with the transmission from the older type sets.

A third factor which has extended the possible field of use of 26 gauge cable is the fact that whereas such cable, up to the present, was available only in the 1818 pair size, the International Standard Electric Corporation have recently announced that such cable is available in a number of sizes from 101 pairs to 1818 pairs, thus allowing a much more flexible layout following closely the actual need for circuits than could be obtained when but one size cable was available.

Future Development

The future development of the toll network will, of course, be dependent upon the extent and volume of demand for additional service, which can only be determined as time goes on.

Detailed cost studies are now under way to determine the possible use of cable on the main toll leads. Although it is still too early for accurate prediction, it appears very probable that as traffic demands grow, certain of the principal open-wire leads will give way to toll cable.

In the local field plans are being prepared with a view to converting before the end of 1935, in addition to Bucarest, the following cities to rotary automatic: Arad, Brăila, Cernauţi, Chişinău, Cluj, Constanţa, Oradea, Craiova, Galaţi, Iaşi, Ploeşti and Timişoara. As has already been mentioned the first of these, Ploeşti, is practically ready for cutover.

The problems which are being encountered in this development of the Rumanian telephone system are complex and interesting in the extreme requiring a knowledge on the part of the engineers of every new phase in the service and practice of electrical communication, and it is hoped that as the plans mature and the results obtained are analyzed a fund of useful knowledge covering all phases of telephone development will be obtained in a form in which it may be made available to all who are engaged in the same work.

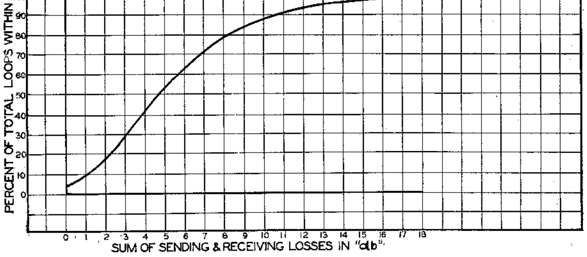

Figure 10—Bucuresti Loop and Trunk Study Two Office Plan, Number of Loops Within a Given Transmission Range. Bell Telephone Manufacturing Company Set.

A New Voice Frequency Telegraph System

By J. A. H. LLOYD, W. N. ROSEWAY, V. J. TERRY, and A. W. MONTGOMERY

International Telephone and Telegraph Laboratories, Incorporated

SYNOPSIS—*This paper describes a new voice frequency telegraph system designed particularly to increase the total telegraph carrying capacity of any given voice frequency telephone circuit. Part I gives general details of the system, including notes on its uses and equipment features, and Part II covers the technical considerations involved in the development of the system.*

PART I

General

THE Voice Frequency Telegraph System described in *Electrical Communication*, Vol. III, p. 288, has given good service for several years and is capable of continuing to do so for many more. However, improvements in the communication art and in apparatus design and equipment practice have offered opportunities to develop the more effective system described in this paper, which is intended primarily to provide up to 18 two-way telegraph channels on a 4-wire cable circuit. Twelve-channel systems of this type are already in operation on 4-wire circuits in Great Britain and France.

In planning the new system, features of the old system which have proved to be most satisfactory were retained. Thus, the speed of signalling remains unaltered at 70 bauds per channel, and although the carrier frequencies have been spaced more closely together, they are still obtained from a motor generator, all being odd harmonics of a common base frequency, now 60

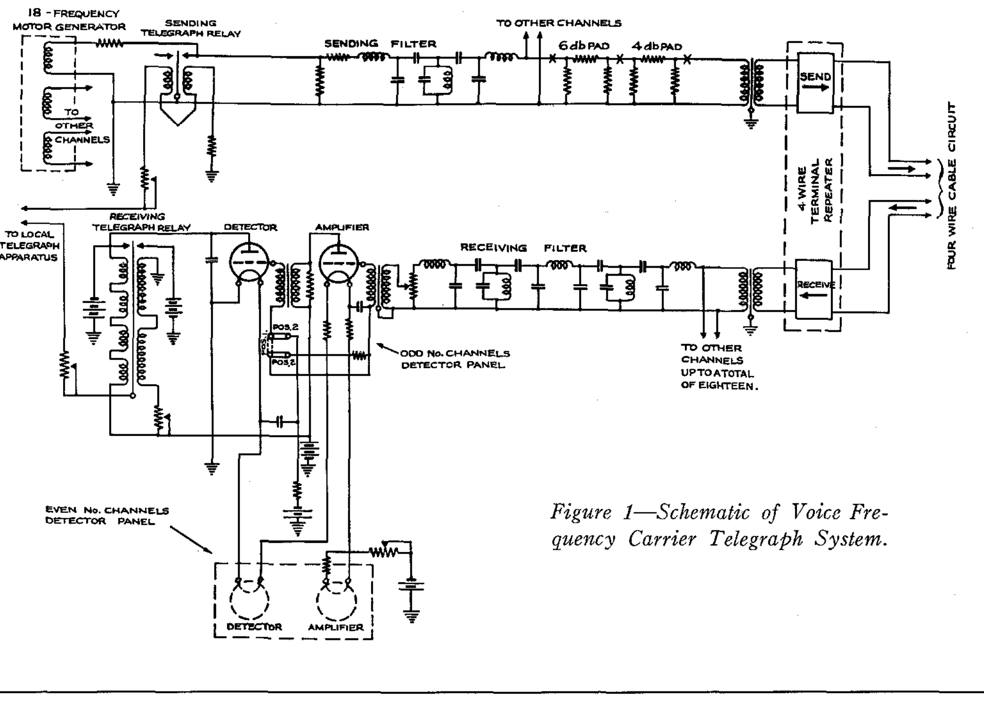

Figure 1—Schematic of Voice Frequency Carrier Telegraph System.

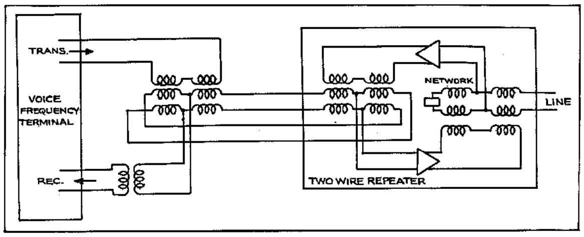

Figure 2—Circuit Arrangement for Two-wire Operation.

p.p.s. instead of 85 p.p.s. The frequencies actually used are shown in Table I, those of corresponding channels in the old system being given for comparison.

TABLE I.

Chan.	New	Old	Chan.	New	Old
1	420	425	10	1500	1955
2	540	595	11	1620	2125
3	660	765	12	1740	2295
4	780	935	13	1860	——
5	900	1105	14	1980	——
6	1020	1275	15	2100	——
7	1140	1445	16	2220	——
8	1260	1615	17	2340	——
9	1380	1785	18	2460	——

The considerable reduction of frequency range used for a given number of channels or, alternatively, the greater number of channels which can be obtained in a specified frequency range, gives the new system an important advantage. It is to be noted that in this, as in all other features dealt with by that body, the system meets the requirements of the C. C. I. T.

A simplified schematic of the complete system is shown in Figure 1. The general principle of operation of the circuit is self-evident, but detectors and filters demand fuller description, as does the equipment as a whole.

Applications

The system can be used over various types of circuit, the most usual of these being the 4-wire loaded and repeatered cable circuit. In this case the 4-wire terminating set used when the circuit is set up for voice transmission is removed and the transmitting and receiving terminals are each connected to one of the two pairs forming the 4-wire circuit. The repeater gains along the line are not altered from their customary values, alterations in gain being made only at the terminal repeaters. It is to be noted that the repeaters are not in danger of being overloaded by the numerous telegraph channels—12 to 18 two-way channels in the usual case—as the maximum load with which each must deal is less than when speech is being transmitted, the maximum power at any point in the line, per channel, being of the order of 100 microwatts. In the operation of the system over actual circuits of this nature, variations in the line equivalent of as much as ±8 db can be tolerated without any need for readjustment of the detectors.

If a 4-wire circuit is not available the system may be operated over a 2-wire circuit, the number of channels in this case being half that obtainable on a 4-wire circuit, since different frequencies are used for transmission in the two directions. The circuit is set up as if for voice operation except that, where not already in use, 2-wire terminal repeaters are added. A hybrid coil scheme, shown in Figure 2, is used to assist in separating transmitting from receiving frequencies.

Of many other possible circuits two may be taken as typical. In the first, indicated in Figure 3, provision is made for communication to and from points along the route. It is evident that different frequencies must be used for communication between A and B, B and C, and C and A, as all frequencies can pass over the whole route. The use of hybrid coils or 4-wire terminating sets at intermediate points enables minimum alteration to be made to the circuit when voice frequency telegraphy is substituted for speech. An additional advantage is that V. F.

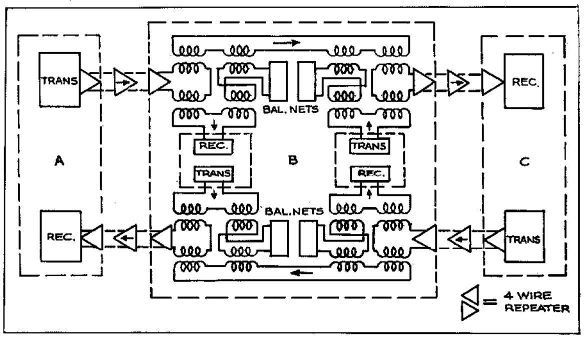

Figure 3—Telegraph Facilities at Intermediate Points (1).

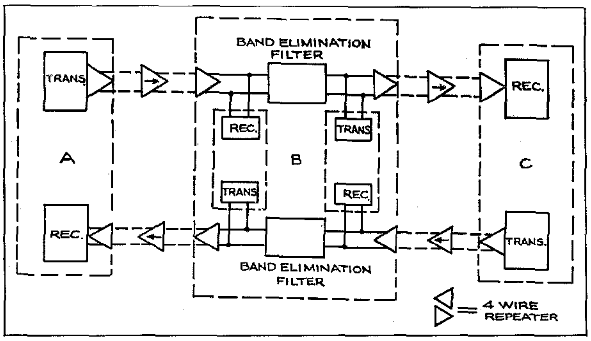

Figure 4—Telegraph Facilities at Intermediate Points (2).

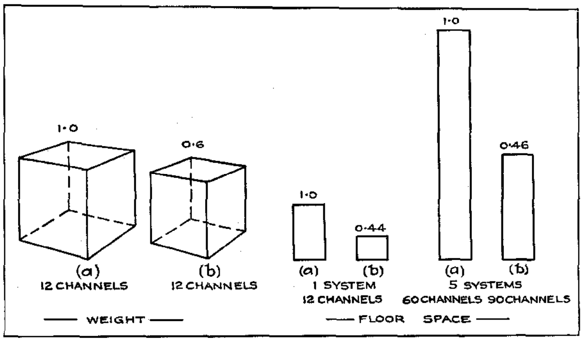

Figure 5—Relative Weights and Floor Spaces of (a) Old and (b) New Systems.

telegraph equipment at the intermediate point can be removed from the circuit if required without interfering in any way with the operation of the end-to-end channels.

In the second circuit, shown in Figure 4, communication is also provided for intermediate points. Since in this arrangement filters are inserted in the line, frequencies already used for communication between one terminal and the intermediate point can also be used for different messages between the intermediate point and the other terminal.

Equipment Features

In giving the circuits physical form, equipment practices and apparatus designs which have been prepared for general use on all toll systems were adopted. As more complete descriptions thereof will appear at a later date, it is only necessary to deal with them briefly in so far as they affect the system described in the present paper.

Three types of bay are used, these being:

(a) Channel bay equipped for 6 channels.
(b) Battery supply and generator bay capable of mounting circuits for ten 18-channel 4-wire systems.
(c) Fuse bay, capable of mounting circuits for five 18-channel 4-wire systems.

Each bay has an iron framework 10 ft. 6 in. high, and occupies a floor space of 1 ft. 8¼ in. x 1 ft. 3 in. An eighteen-channel system requires five bays, i.e., one fuse bay, one battery supply and generator bay and three channel bays, and so occupies a floor space of 8 ft. 5¼ in. x 1 ft. 3 in. Figure 5 affords an interesting comparison between the sizes and weights of a 12-channel system of the new and old types.

By mounting individual pieces of apparatus on one side of a mounting plate only, with all wiring tags towards the front of the panel, it is possible to equip panels on both sides of a rack framework. With newly developed mounting plates and apparatus this proves to be an eco-

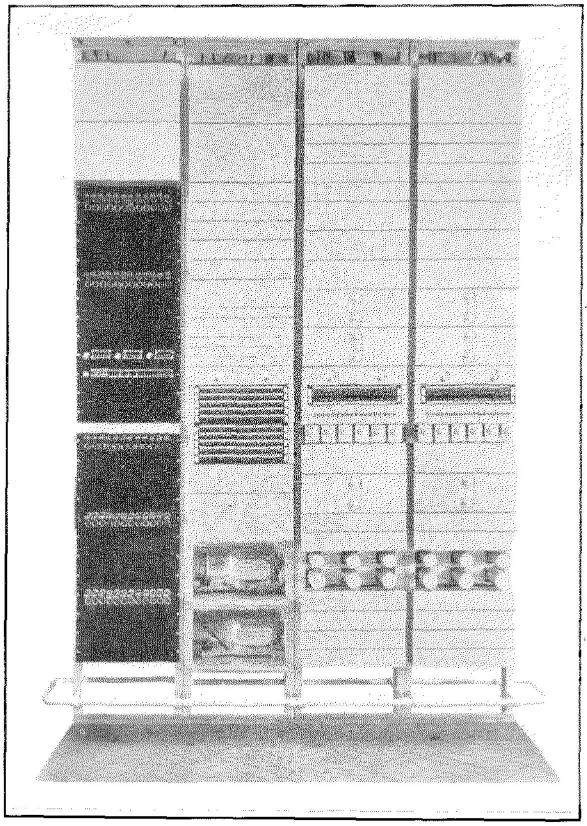

Figure 6—Complete Equipment, Front View.

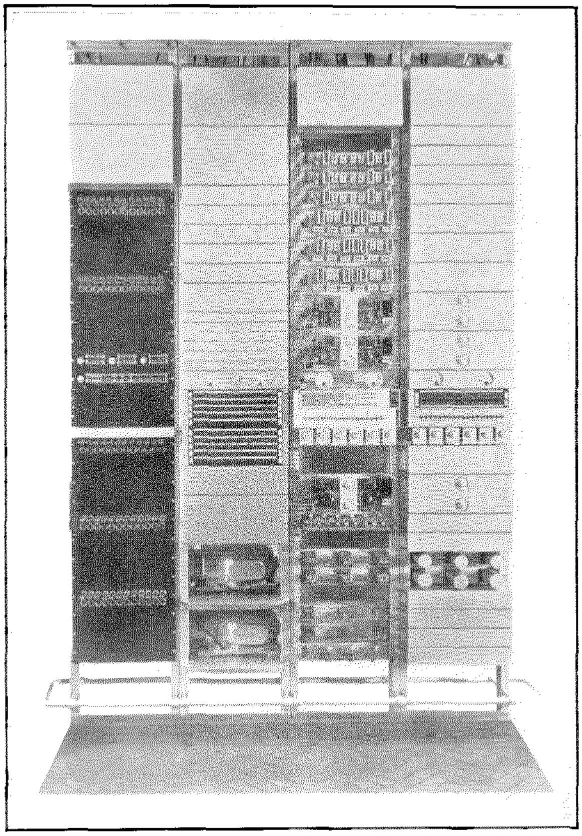

Figure 7—Complete Equipment, Front View, Showing Covers Removed From One of the Channel Bays.

nomical solution of the equipment problem. Wiring remains entirely accessible and complete circuits are to be found on each side of the rack.

All panels project from the rack by a uniform amount ($3\frac{3}{4}$ in.), and covers of this height are provided for most panels. This applies also to the main terminal strips at the top of the bays which are mounted on both sides of the rack, staggered relatively to each other on the two sides to make wiring accessible. Where apparatus, such as jacks, keys, meters, etc., must be continuously visible for operating reasons, other arrangements are made, and these can be seen from the photographs, Figures 6, 7, and 8, which also show the general appearance of the system. A mounting of particular interest is that for jacks and keys. This is hinged so that the single-sided mounting system can be adhered to while still keeping the wiring accessible. The cable form leading to the jacks or keys hinges from the main cable form, which runs along the inside of the channel irons of which the racks are made.

It was decided to abandon the practice of connecting meters permanently in the local telegraph sending and receiving legs (formerly necessary when the concentration of so many channels on one bay had not been accomplished) and to provide one set of meters, located on each side of a bay, for use on any channel by simple patching between jacks provided in the jack field.

A special meter incorporating a metallic oxide rectifier is used for measuring the output voltages from the various windings of the voice frequency generator.

Protection has been provided by the use of resistance lamps in plate and telegraph circuits and by fuses in filament circuits, lamps and fuses

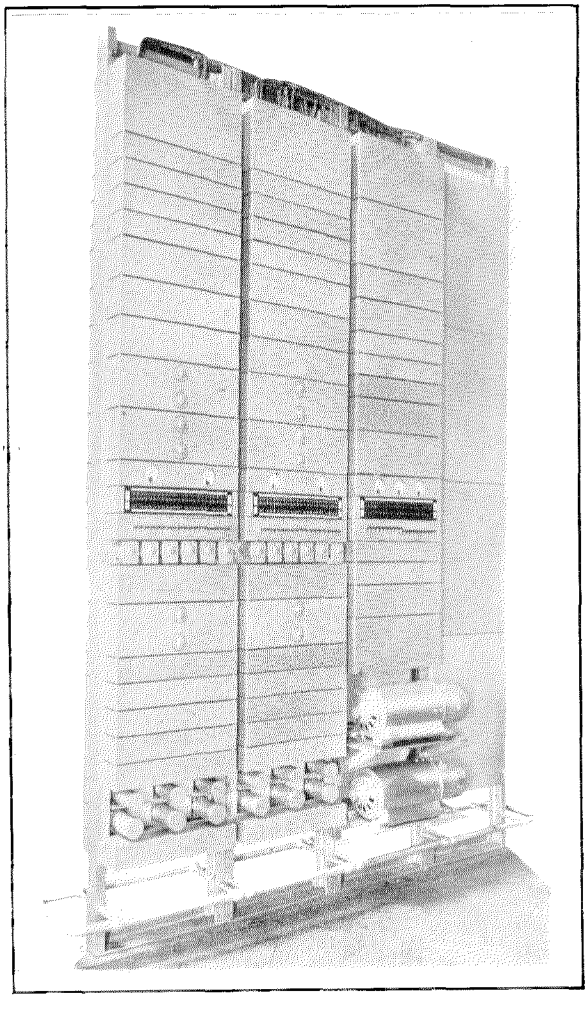

Figure 8—Complete Equipment, Rear View.

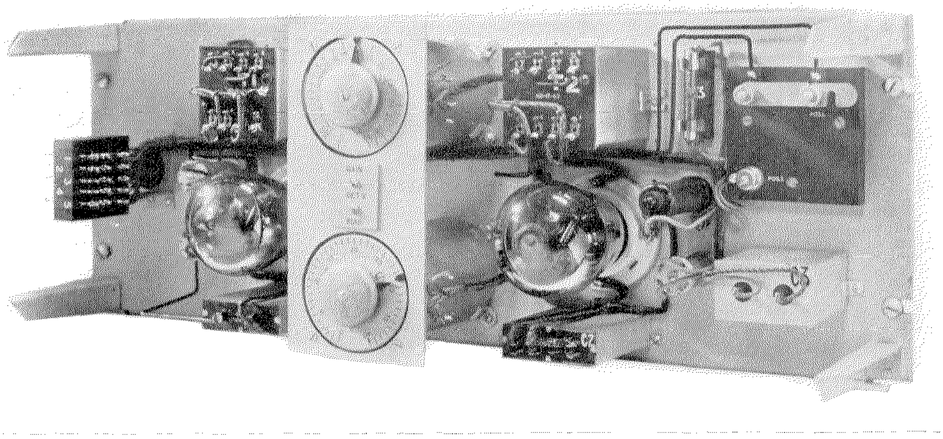

Figure 9—Detector Panel.

being mounted on panels made from Sindanyo, a fire-resisting compound. Dummy panels on the fuse bay are also of this material. The customary alarm circuits indicate failure of any of the current supplies.

New Apparatus

Of the new apparatus designs which have assisted in enabling the new equipment ideas to be put into practical use, the following may be briefly mentioned:

Mounting Plates—The use of thin steel mounting plates (0.078 in. thick) strengthened by means of a double flange running across their lengths has contributed to the reduced weight of the equipment. All apparatus is held to these plates by means of screws, this type of plate being very easy to drill and tap. A detector panel of the system, shown in Figure 9, illustrates these points.

Condensers—Paper condensers have been reduced in size by the use of "Halowax" as an impregnating compound; a more constant temperature-capacity curve also results. A new manufacturing process applied to mica condensers has led to better stability and reduced losses, phase angles regularly obtained being of the order of ½ minute.

Coils—As Permalloy has been used in the cores of the transformers, repeating coils and inductances, a considerable reduction in size has been possible without detriment to efficiency. A note on the coils used in the filters appears elsewhere in this paper.

Mouldings—Much use has been made of moulding in producing the new apparatus. Resistance spools and valve sockets have been moulded in Steatite, and many parts of a new potentiometer are formed of a moulded phenol product.

Valves—Two valves of different types are used in each detector. Both take 0.25 amp. filament current, and as the valves of two detectors are connected in a series filament circuit, the total filament current drain for an eighteen-channel system is thus only 2.25 amps.

PART II

TECHNICAL CONSIDERATIONS INVOLVED IN THE DEVELOPMENT

In order to make clear the reasons for using the types adopted it is necessary to enter into some discussion of what is involved in the reception of voice frequency telegraph signals.

The essence of any telegraph channel is that it should indicate at one end the instant at which changes of some sort or another are effected at the other end, although a delay in the indications is immaterial so long as it is the same for all changes.

With some telegraph codes it is essential also to distinguish between different kinds of changes made at the transmitting end; but with the majority of codes it is otherwise. In the latter the changes (or signals as we shall presently call them) may be of one sort only, or of two sorts identical except in sense, in which case they are used alternately to prevent cumulative changes in the telegraph channel; the Morse (land) code, the teleprinter code and the Baudot code are examples of this class. It might at first sight be thought that these codes demand the ability to distinguish between marking and spacing currents, but this is not so; in each the beginning of a letter, word, or message can be identified by consideration only of the intervals separating signals; thus, in the Morse code an interval of five time units precedes the beginning of each word, in teleprinter code an interval of a definite fractional number of time units denotes the beginning of a letter, and in the Baudot code the synchronising signal, recurrent at intervals of 12, 17, or 22 time units, provides the same information, though not so readily. There are, nevertheless, several disadvantages attaching to a telegraph channel that is not inherently capable of distinguishing between the signals which start marks (positive signals) and those that stop them (negative signals). Of these the most important is that all automatic telegraph receivers at present available require the first signal of every message to be of the same polarity, and a special attachment would be necessary to make them independent of such restriction.

With these considerations in mind it is interesting to review some of the large number of methods which may be employed to convey telegraph signals through a channel using alternating currents restricted to a narrow band of frequency.

The first and second methods are closely related, signals being transmitted in one by momentary application of a current to the line, and in the other by momentary withdrawal of the current from the line. A third method consists in transmitting a steady alternating current whose phase is reversed for each signal (closely resembling double current working in ordinary telegraphy). The almost universally adopted arrangement of transmitting an alternating current to indicate a positive signal and suppressing it to indicate a negative signal is a fourth method; and variations of this method in which positive signals are marked by the transmission of an alternating current of one frequency and negative signals are indicated by the transmission of current of another frequency constitute a fifth system. Because they make no distinction between positive and negative signals, the first three methods are unsuitable for

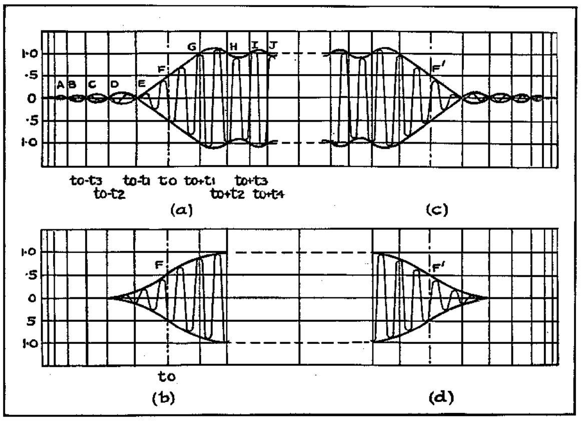

Figure 10-a, b, c, d—Oscillations Resulting From Positive and Negative Signals.

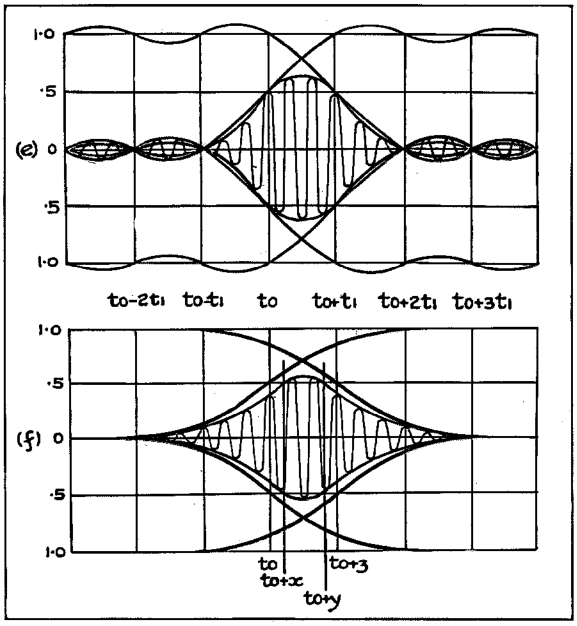

Figure 10-e, f—Oscillations Resulting From One Positive Signal Closely Followed by One Negative Signal.

general use; this is to be regretted, as they each possess considerable advantages. The fourth method has the beauty of simplicity and, compared with the fifth method, economises in both frequency range and selective circuits. In combination these economies are more than sufficient to justify the choice of the fourth method notwithstanding the difficulties that attach to it in actual practice. These difficulties centre round the slow but unavoidable variations which take place in the strength of the signals when transmitted to a distance, and will be best understood by consideration of the following simple example:

Imagine a telegraph channel consisting of a source of constant frequency oscillations whose output is controlled by a sending relay, a transmission path passing a narrow symmetrical band of frequencies, a rectifier, a low pass filter, and a receiving relay with controllable bias. For the sake of simplicity we may imagine that the frequency of the oscillations lies in the middle of the pass range of the transmission path, and that the phase change in transmission is proportional to frequency. It will further aid our consideration to assume that both relays are ideal, that is to say, that the sending relay acts instantaneously in response to control currents, and the receiving relay also operates instantaneously to mark or to space whenever the current in its windings rises above, or falls below, a given amount which is the effective bias current. With the assumptions made, the envelope of the oscillations after transmission would take on one or other of the forms illustrated in Figures 10 (a) and (b) following the transmission of a positive signal, (beginning of transmission of oscillations). The transmission properties assumed (which, although theoretically impossible of exact realisation, are good approximations to actual conditions) cause those envelopes to assume skew symmetry about the point F, at which the amplitude reaches half its steady state. Figure 10 (a) shows the kind of envelope resulting from a transmission path with sharp "cutoffs" at each end of the transmission range; more gradual cut-off would result in the envelope shown in Figure 10 (b). By control of the attenuation characteristic of the transmission path it is theoretically possible to make $t_1 = \frac{1}{2} t_2 = \frac{1}{3} t_3$, etc., a procedure which has big advantages if it is necessary to signal only at a speed $\frac{1}{t_1}$ bauds.

Types of Detector Considered

The oscillations are not suitable for direct operation of the receiving relay, since the latter (being ideal) will follow the rise and fall of each oscillation which exceeds the value of the relay bias. The oscillations must therefore be rectified, and when this has been done a new current is obtained whose amplitude at any instant is related to that of the original wave at the same instant, but in general is not proportional to it. The rectified current is, however, still unsuitable for application to the relay since it reaches zero value as many times as the original wave, and would cause the relay to vibrate in a similar way. A low pass filter strongly attenuating all frequencies passed by the transmission path obviates this difficulty and produces a current having smooth variations. This filter (which in practice usually consists of the inductance of the relay and a single condenser in shunt) should pass a band of frequencies at least as wide as that passed by the original path, with uniform efficiency and linear phase change. If it fulfills these conditions and the rectifier has a simple characteristic without discontinuities, the output from the filter will be a current whose amplitude is a delayed replica of the envelope of the rectified current. Allowing for this delay (which, being constant, is of no effect) the value of the rectified current at any instant is dependent only upon the value of the original input to the detector at the corresponding instant, no matter whether the amplitude be rising or falling or constant.

From this it follows that the receiving relay will operate whenever the incoming oscillations pass through the value at which the rectified current counterbalances the relay bias, and the characteristic of the rectifier (so long as it is simple and not variable with respect to time) will not influence the transmission of signals at all. A special interest attaches to this property, although it is strictly true only for telegraphy with ideal relays, because of the great importance formerly attached to the form of static rectifier characteristics.

Referring to Figures 10 (a), (b), (c), and (d) it is seen that if the intervals between the operations of the receiving relay are to be the same as those separating the original signals, the value of the relay bias must be equal and opposite to the rectified current corresponding to the amplitude of the oscillations at the points F and F^1, i.e., half the steady state amplitude. The repetition will not, however, be exact if the signals follow one another so closely that the transient oscillations associated with one have not died down before the arrival of the next. Figure 10 (f) illustrates the production of distortion in this way, by showing the oscillations resulting from the receipt of a positive signal followed after an interval z by a negative signal. The thin lines indicate the envelopes of the oscillations produced by the signals individually, and the thick line the result of combining the two. It will be seen that instead of operating at times t_o and t_o+z the relay will operate at times t_o+x and t_o+y, introducing distortion $(x+z-y)$. Figure 10 (e) illustrates the interesting case in which transient oscillations introduce no such distortion, although the transients following the receipt of the positive signal are still quite strong when the negative signal arrives. The absence of distortion is due to the fact that the signals are transmitted at integral intervals of the period t_1, and that at every such interval the envelope of oscillations passes through its initial or final value.

By resorting to this device a telegraph channel can be made to operate with small distortion at a speed in bauds closely approaching the band width of the transmission path; but because it cannot be made to work so well at all slower speeds the principle is not suitable for ordinary carrier telegraph systems. Accordingly, oscillations of the type shown in Figures 10 (a) and (c) will not be further considered, and it will be assumed that signals are transmitted at sufficiently wide intervals to avoid distortion of the type illustrated in Figure 10 (f).

The effect of varying signal strength upon the reception of signals will be seen on reference to Figure 11. If the relay bias is set for correct reception of the larger amplitude so that signals are received at times t_o and t_1, then if the amplitude of the oscillations is reduced to the smaller value the receiving relay operates at times t_o+x and t_1-x introducing a distortion of 2x.

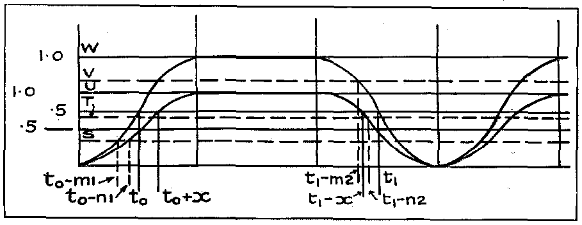

Figure 11—Effect of Variation of Amplitude on Detectors of Types 1 and 2.

One method of overcoming this difficulty is to employ a detector of what we may call type 2. This differs from the one already considered (which we may call type 1) in that the sensitivity of the detector characteristic varies, not only with the load applied, but also with time.

Figure 12 shows the circuit for a type 2 detector and Figure 13 its characteristic.

For slow variations of input the rectified current follows the curve O P A C E both upwards and downwards, and P marks the point at which the peak input voltage exceeds the grid bias voltage and grid current commences to flow, charging up condenser C (Figure 12) and increasing the grid bias. If, when the current has the magnitude A, it is suddenly reduced before the condenser C has time to discharge through the resistance R, the rectified current follows the curve AB. Similarly a rapid descent from an input voltage corresponding to the points C or E causes the variation of rectified current to follow the curves C D O or E F O.

The use of a detector of this type in conjunction with a relay bias corresponding to the rectified current produced by amplitude OS (Figure 13) causes a positive signal to be received at time t_o-m_1 or t_o-n_1 according to the signal amplitude, and a negative signal to be received at time t_1-m_2 or t_1-n_2. These time values are obtained by comparison between Figures 11 and 13 where it can be seen, for example, that OT is the input voltage giving the same rectified current when the input descends rapidly from the value OU, as is given with a rising input by the input OS; and if this be suitably chosen m_2 may be made equal to m_1, and n_2 to n_1, so that variation of input need not distort the signals. It is, of course, necessary for successful working in this way that the condenser C should retain its charge while the input current falls from OW

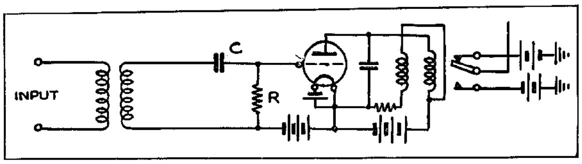

Figure 12—Schematic of Detector of Type 2.

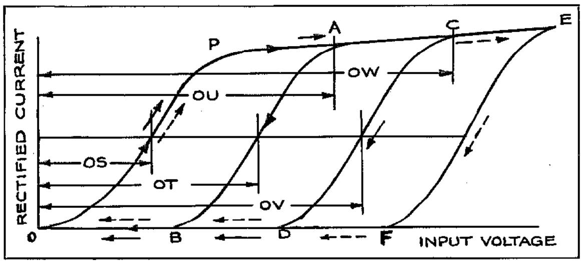

Figure 13—Hysteresis Characteristic of Detector of Type 2.

to OV, or from OU to OT, and yet it must be completely discharged in time for the next signal. In practice this cannot be done sufficiently well to prevent serious distortion without greatly reducing the speed of signalling, or having recourse to auxiliary apparatus such as a relay operated by the receiving relay and arranged to short-circuit resistance R during spacing periods, whereby the discharge of condenser C is hastened after the receiving relay has operated in response to a negative signal. Detectors of type 2 therefore lie between the Scylla of slow speed and the Charybdis of complexity.

Another and entirely different method of overcoming the difficulty of variation of amplitude is to use "impulse" working. This demands for perfection a detector (type 3) of which the output of rectified current is approximately proportional to the input of alternating current, together with a network the transmission efficiency of which from zero frequency up to a frequency equal to the band width of the transmission path is proportional to frequency, and which produces a phase change commencing at 90 deg., and varying uniformly with frequency. The output from such a network is a current whose magnitude is proportional to the rate of rise or fall of the input current, and it may therefore be called a "differentiating network." Figure 14 shows the result of applying to a differentiating network the current obtained by rectifying oscillations of the types shown in Figures 10 (b) and (d). The full lines show the results obtained with isolated signals and the dotted line the result of positive and negative signals following as closely one upon the other as could be permitted in general practice. The relay used with such a combination should operate for a positive signal when the impulse current reaches the value OA, and should be arranged not to operate again for a negative signal until the current reaches the value OB (OB = −OA). The insensitivity of an ordinary relay may suffice but a sensitive relay with the holding arrangement shown in Figure 15 is better. Figure 14 also shows, in the difference between the full and dotted lines, the distortion introduced on account of the close proximity of adjacent signals. With the amplitudes shown this is small, but would greatly increase for larger amplitudes (equivalent to reducing OA and OB), since operation due to the first signal would be hastened relative to that due to the second. Given a linear detector, impulse working eliminates very completely the effect of amplitude variation in producing bias, but to avoid other forms of characteristic distortion the signalling speed for a given transmission band must be diminished, as the differentiating network considerably extends the time occupied by transients following a signal. Another difficulty with this form of detector is the large amount of power with which the detector has to deal without overloading. For example, for a range of ±5 db in the efficiency

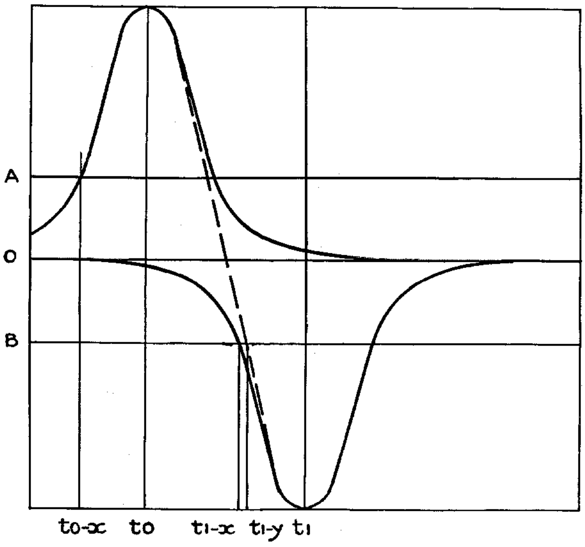

Figure 14—Impulse Working (Type 3 Detector).

of the transmission path, the detector must be capable of giving ten times the minimum power required for satisfactory operation of the relay. Impulse working also renders a telegraph system very liable to false operation by interference owing to the small force holding the relay between widely separated pulses.

When an impulse circuit is used in combination with a detector not having a linear characteristic, independence of amplitude is sacrificed but the disadvantageous sensitivity to interference may be reduced.

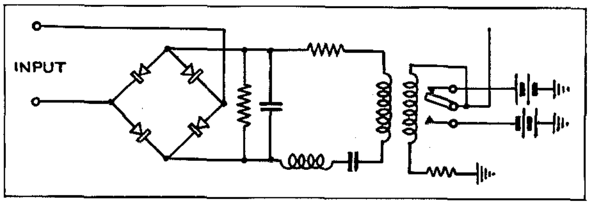

Figure 15—Schematic of Detector of Type 3.

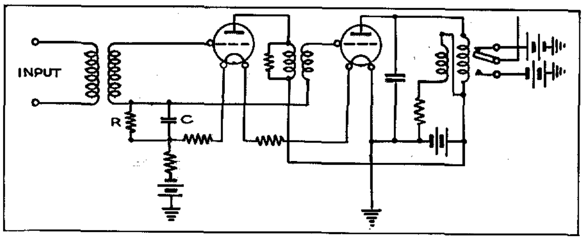

Figure 16—Schematic of Detector of Type 4.

Description of Detector Finally Adopted

In an attempt to combine the advantages of a detector of type 1 with an ability to tolerate variations of amplitude, an amplifier detector has been devised in which the gain of the amplifying valve is controlled by the maximum value of the input voltage. For this purpose advantage is taken of the fact that with all ordinary telegraph systems the intervals not spent in the repose conditions are short, and by arranging that current is transmitted during repose periods, the gain of the amplifier may be kept adjusted and ready for signalling. It differs from an amplifier detector of type 2 in that during periods of no input the gain rises very slowly, so that no appreciable change occurs during the longest of such periods necessitated by the telegraph code. The gain is, however, reduced very rapidly to the required value upon the reception of alternating current, so that even a very short period in the repose condition will enable the detector to adjust itself.

It would have been possible to make an amplifier with this property which could have been used in conjunction with any detector of type 1, but it was found simpler to combine it with a detector in a somewhat different circuit to make what may be described as a detector of type 4, the circuit of which is shown in Figure 16. It consists of an amplifying valve, transformer coupled to a detector valve, and the special features lie in the method by which grid bias is supplied to the two valves. The return ends of the secondary windings of both transformers are connected together and to the filament circuit through a condenser and resistance. The filaments of the valves are connected in series through resistances, so that the amplifier has sufficient grid bias for efficient amplification when the detector valve has the minimum bias necessary to reduce its plate current to a very small value with no input to the detector. When the amplifying valve receives such input that, even when amplified, the peak voltage applied to the detector valve remains less than the original grid bias voltage, no grid current flows and the detector behaves as if it were of type 1. When, however, the input is increased beyond this amount, grid current flows, increasing simultaneously the grid bias of both valves. The amplifying valve has a higher amplification factor than the detector valve and is accordingly more affected, its gain being reduced while, to a less extent, the sensitivity of the detector is reduced also; the reduction continues until the peak value of the input to the detector is just a little greater than the new grid bias voltage. Hysteresis characteristics of the new detector are shown in Figure 17. They resemble somewhat the characteristics of a detector of type 2 but differ in an important respect which is made clearer in Figure 18. Here the characteristics are redrawn with the input voltage expressed as a fraction of the maximum value. It will be seen that, though with differing inputs rectified current starts at different fractions of the maximum input voltage, and though it reaches different maxima, yet for an input of half the maximum value it always produces the same rectified

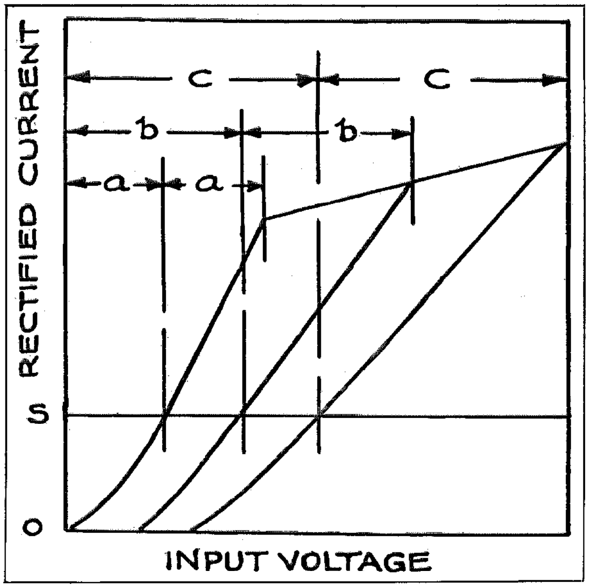

Figure 17—Hysteresis Characteristics of Detector of Type 4.

current. Since it is at the rectified current corresponding to an input of half the steady state value that the receiving relay must work, this is the most important consideration. It is interesting, however, to note the reason for the increase of maximum rectified current with input voltage. With large input voltages the grid bias of the amplifier valve is high and its output is much distorted by the introduction of even harmonics; one-half of the wave is low and long, the other is short and high. Since the positive peak voltage applied to the detector is adjusted almost to a constant value it is easy to see that the long low half wave rectified will produce a bigger current than the short high one. If the secondary of the interstage transformer is reversed so that the other half wave is rectified, the maximum rectified current will diminish with increase of input and an unsuitable characteristic like that shown dotted in Figure 18 will be produced. This characteristic is unsuitable, not because of the low value of maximum rectified current, but because it does not provide a constant value of rectified current for half the maximum input voltage.

A resistance is shunted across the primary winding of the interstage transformer to increase the sensitivity of the amplifier to change of grid bias. When the bias is altered the internal impedance of a valve changes more rapidly than its magnification factor, but the voltage amplification obtained from a valve and transformer is almost entirely determined by the amplification factor if the load has a high impedance. With a low impedance load, variation both of impedance and amplification factor are effective to vary gain. Rather than use a different value of transformer inductance for each different frequency in order to obtain the correct low impedance in the plate circuit of the valve, a shunt resistance has been used which is suitable for any frequency within the voice range.

It is clearly desirable to supply the amplifier-detector with current during the repose condition so that its gain may remain suitable for the reception of signals whenever they may be transmitted. In teleprinter circuits, marking is usually the repose condition; hence alternating current is transmitted for a mark. For Baudot, on the other hand, spacing is the repose condition, and so, on channels used for Baudot or similar work, alternating current should be transmitted for a space. Any inversion of a channel necessary to fulfill this condition can be readily carried out

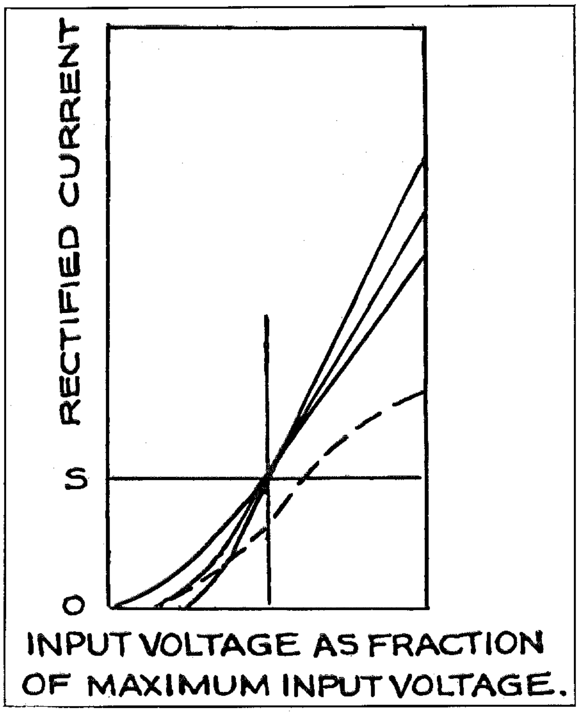

Figure 18—Hysteresis Characteristics of Detector of Type 4. (Input Voltage as Fraction of Maximum Input Voltage).

by keys provided on the system for reversing the sending relay and the receiving relay battery polarities.

It is necessary for the successful application of a detector of type 4 that the characteristic of the transmission path should not produce oscillations of the types shown in Figures 10 (a) and (c), since these, by rising above the steady state value, reduce the gain of the amplifier detector below its proper value. This condition is not normally met, since oscillations of this type are only produced by filters having a much squarer characteristic than can economically be used in practical systems.

Filters

As is always the case, the economical design of sending and receiving filters involved compromise between electrical transmission characteristics and cost.

As regards transmission characteristics the following general requirements had to be satisfied:

(a) The attenuation characteristic was to be symmetrical about the mid-band frequency, i.e., the attenuations introduced by the filter at frequencies equidistant above and below the mid-band frequency to be approximately equal.

(b) The phase characteristic was to be of equal and opposite symmetry about the mid-band frequency, to pass through zero at, and to approximate closely to a straight line±35 p.p.s. from, the mid-band frequency.

Among the particular transmission requirements to be satisfied, the following may be mentioned:

(a) The attenuation of each receiving filter± 35 p.p.s. from its mid-band frequency was to be not more than 2.5 db above that at its mid-band frequency.

(b) The attenuation of each receiving filter±120 p.p.s. from the mid-band frequency, i.e., at the mid-band frequencies of the filters directly adjacent to it, was to be not less than 30 db above that at its mid-band frequency.

In view of the above requirements the so-called "confluent" band pass filter section of the constant k type has been employed as the basis of design, since it satisfies them very closely, and its simplicity makes it satisfactory economically. The use of derived or "m" type filter sections was considered, but they did not appear to offer any considerable advantage over the prototype section, and their greater complexity would have increased the cost of the filters.

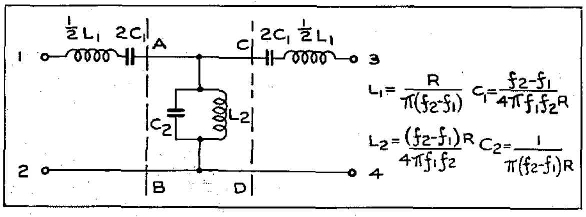
$\frac{1}{2}L_1$ $2C_1$
A
C
$2C_1$ $\frac{1}{2}L_1$
1
3
C_2
L_2
2
4
B
D
$L_1 = \frac{R}{\pi(f_2-f_1)}$
$C_1 = \frac{f_2-f_1}{4\pi f_1 f_2 R}$
$L_2 = \frac{(f_2-f_1)R}{4\pi f_1 f_2}$
$C_2 = \frac{1}{\pi(f_2-f_1)R}$

Figure 19—Prototype Band Pass Filter Section.

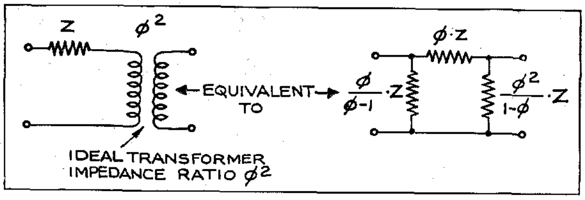
Z
ϕ^2
EQUIVALENT TO
$\phi \cdot Z$
$\frac{\phi}{\phi-1} \cdot Z$
$\frac{\phi^2}{1-\phi} \cdot Z$
IDEAL TRANSFORMER IMPEDANCE RATIO ϕ^2

Figure 20—Equivalence Used in Designing Impedance Transforming Filter Sections.

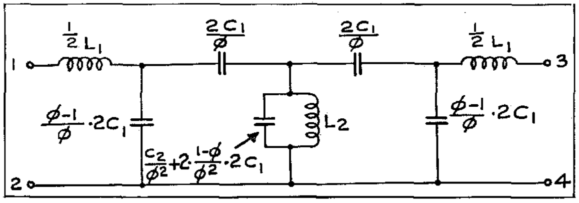
$\frac{1}{2}L_1$
$\frac{2C_1}{\phi}$
$\frac{2C_1}{\phi}$
$\frac{1}{2}L_1$
1
3
$\frac{\phi-1}{\phi} \cdot 2C_1$
L_2
$\frac{\phi-1}{\phi} \cdot 2C_1$
$\frac{C_2}{\phi^2}+2 \cdot \frac{1-\phi}{\phi^2} \cdot 2C_1$
2
4

Figure 21—Band Pass Filter Section, With Internal Impedance Transformations Electrically Equivalent to Figure 19.

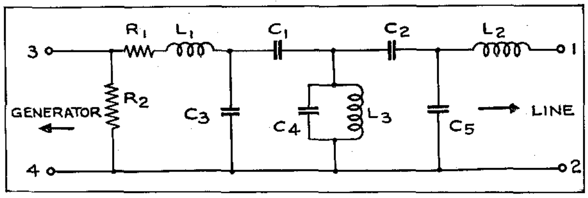

Figure 22—Sending Filter Schematic.

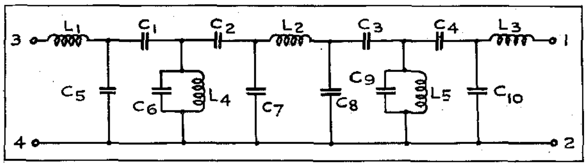

Figure 23—Receiving Filter Schematic.

To satisfy the particular attenuation requirements, a single section has been used for each sending filter, and two sections for each receiving filter.

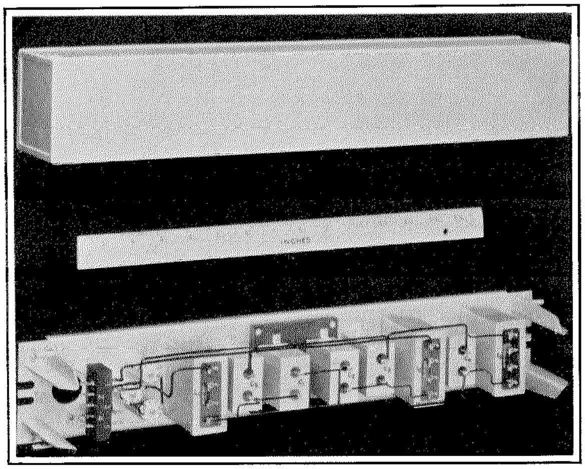

Figure 24—View of Sending Filter.

On Figure 19 is represented a full section, with mid-series termination, of the basic structure, together with the formulae for calculating the impedance elements. In these formulae f_1 and f_2 are the lower and upper cut-off frequencies, respectively, and R the impedances between which the filter is to be inserted, R for the filters concerned being a pure resistance of 600 ohms; the band width $(f_2 - f_1) = 120$ p.p.s.

From a consideration of the equations given in Figure 19 it is seen that the condenser C_2 is of constant magnitude if the band-width $(f_2 - f_1)$ and the impedance R are constants and, for the values of these factors given above, is found to be 4.421 μF. Further, since the band-width is small compared with the product of the cut-off frequencies, the formula for the inductance L_2 shows that the latter is of a relatively small value and decreases progressively as the frequency increases. At the lowest carrier frequency, 420 p.p.s., its value is 0.033 henrys; at the twelfth carrier frequency, 1740 p.p.s., its value is 0.0019 henrys; and at the eighteenth carrier frequency, 2460 p.p.s., its value is 0.00095 henrys.

From both the economic and the electrical standpoints, the values of both L_2 and C_2 are very unsatisfactory. Thus, the condenser C_2 of value 4.421 μF would, on the basis of reasonable cost, have to be of the paper dielectric type, a type which is difficult to adjust within close limits, has high dielectric losses, and is subject to large variations with respect to temperature and time. Again the low values of the inductances L_2 would cause considerable difficulties in their manufacture to within close limits; for example, on the type of coil it was proposed to use in these filters an inductance of 0.0019 henrys would require about 120 turns, so that the removal or addition of only one turn would vary the inductance by ±1.5%, a variation considerably in excess of that permissible from a consideration of the transmission requirements.

To avoid the difficulties thus presented, use has been made of impedance transforming filter sections effectively, obtained by introducing an ideal step-up transformer at the section AB of the filter shown in Figure 19, and an ideal step-down transformer at the section CD.

The equivalence used in designing such filter sections is shown in Figure 20 and by applying it to the structure of Figure 19, in which the condenser $2C_1$ forms the impedance Z of Figure 20, the equivalent structure of Figure 21 is obtained.

It will be noticed that the number of elements has been increased, three shunt condensers being required in place of the one shunt condenser of Figure 19, but the advantages gained by the use of this structure more than offset the increase in number of elements. Thus, by a suitable choice of ϕ, the condenser C_2 can be reduced in value

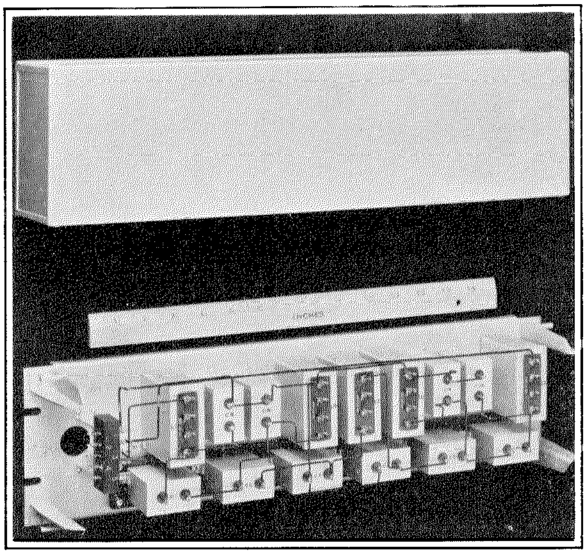

Figure 25—View of Receiving Filter.

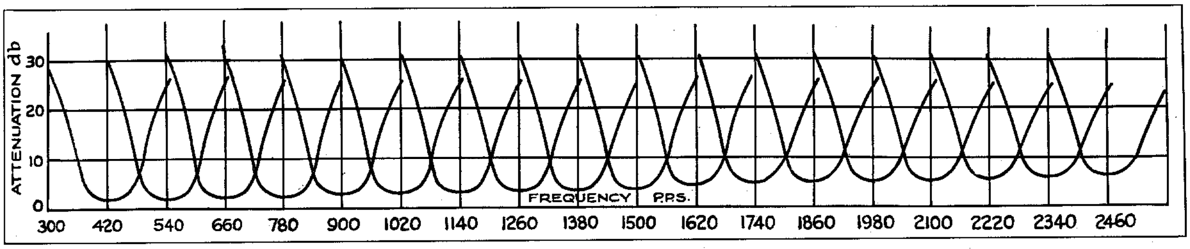

Figure 26—Attenuation Characteristics of Sending Filters for 18 Channel System.

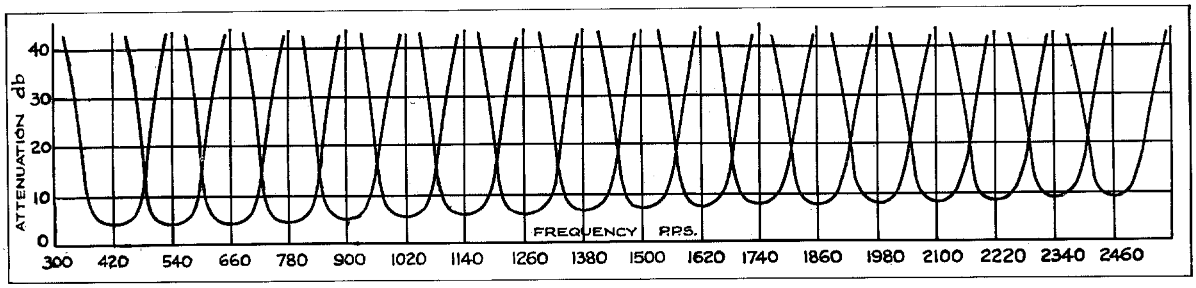

Figure 27—Attenuation Characteristics of Receiving Filters for 18 Channel System.

until it can be manufactured as a mica-dielectric type of the same dimensions as the rest of the condensers in the structure, thereby standardising the type of condenser. Furthermore the use of mica-dielectric condensers offers important advantages as they are readily adjustable within close limits, have low dielectric losses and high stability. Similarly the shunt inductance $\phi^2 L_2$ can be brought to a value of the same order as the series inductances, and therefore can be manufactured to the same limits and electrical efficiency. The series condensers $\frac{2C_1}{\phi}$ are of low value compared with the shunt condensers, but it can readily be shown that they can vary within relatively wide limits without appreciably affecting the performance of the filters.

A further simplification of the structure is obtained by making all the shunt condensers of equal value. This, of course, fixes the value of ϕ, which is then given by the relation

$$\phi = \tfrac{1}{2}\left(\sqrt{\frac{2C_2}{C_1}+9}-1\right)$$

Table II gives the values of the factors ϕ, ϕ^2 and the impedance elements of the filters for the 1st, 12th and 18th channels.

TABLE II

Channel	1	12	18
Mid-band frequency p.p.s.	420	1740	2460
ϕ..................	4.62	20.04	28.52
ϕ^2................	21.34	402	814
$\tfrac{1}{2}$ L_1 (Henrys)..........	0.796	0.796	0.796
L_2 (Henrys)..........	0.708	0.762	0.772
$2C_1 \frac{\phi-1}{\phi}$ (μF)..........	0.1443	0.01	0.005080
$\frac{2C_1}{\phi}$ (μF)..............	0.03987	0.000525	0.000185

All the filters are of the unbalanced type having a theoretical band-width of 120 p.p.s. and a characteristic impedance of 600 ohms, being terminated at $x = 0.8$ at the common ends, and at $x = 0.5$ at the ends that are not common. The general schematics for the sending and receiving filters and photographs of a sending filter panel and a receiving filter panel are shown on Figures 22, 23, 24, and 25. The resistances R_1 and R_2 shown on the sending filter schematic, Figure 22, serve both to adjust the power output of each channel and to prevent too large a change in the impedance facing the input of the filter for the open and closed position of the transmitting telegraph relay.

The coils and condensers for each filter are mounted on one side of a thin steel mounting plate, the dimensions of the latter being 19 in.

x 3½ in. for the sending filters, and 19 in. x 5¼ in. for the receiving filters; both sending and receiving filters are provided with dust covers 3¾ in. high. A considerable reduction in weight has been obtained as compared with the filters employed on the older system, as can be seen from Table III.

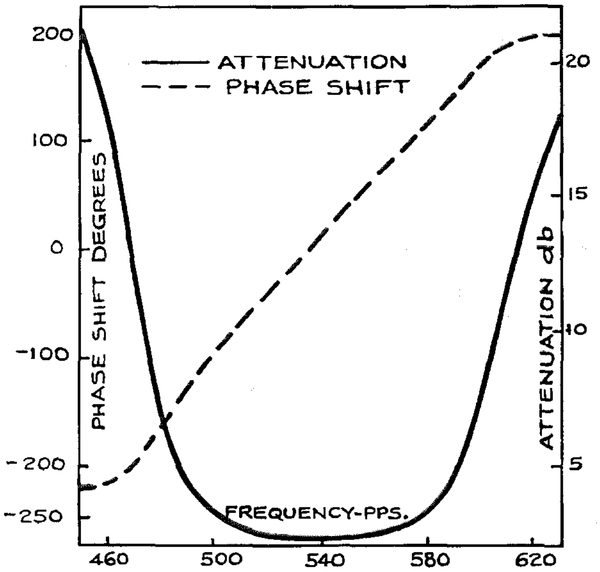

Figure 28—Attenuation and Phase Shift of Sending Filter Flanked on Both Sides.

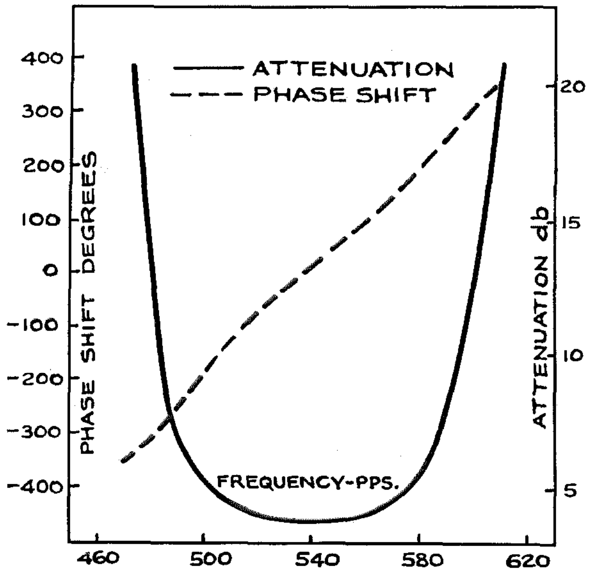

Figure 29—Attenuation and Phase Shift of Receiving Filter Flanked on Both Sides.

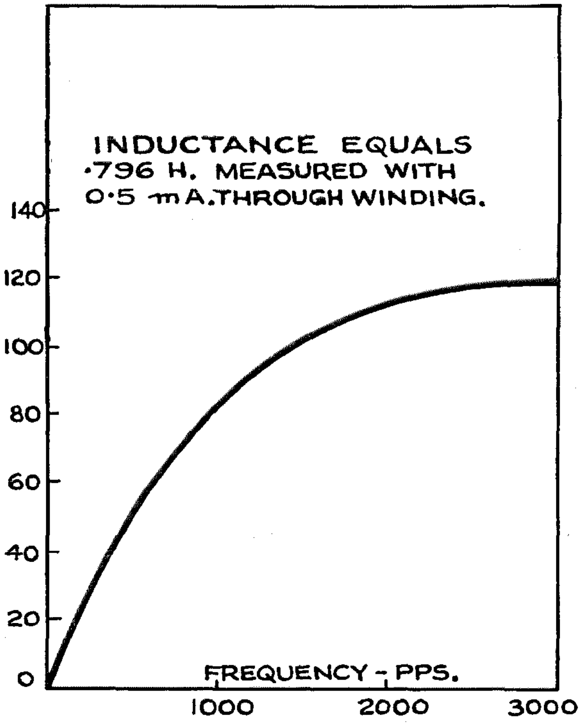

Figure 30—Filter Retardation Coils Variation of "Q" = $\frac{wL}{R}$ With Frequency.

TABLE III

	Old System	New System
Weight of sending filter.............	17 lb. = 7.7 kgm.	6 lb. = 2.8 kgm.
Weight of receiving filter.............	27 lb. = 12.5 kgm.	10 lb. = 4.5 kgm.

These reductions are due to the use of a thin steel mounting plate, and to the reduced size and weight of the filter elements.

Some representative transmission characteristics are given in Figures 26, 27, 28, and 29. Figure 26 shows the attenuation characteristics of the sending filters for channels 1 to 18 measured with the filters paralleled on the output side and the input attenuation pads removed, and Figure 27 shows similar characteristics for the receiving filters with the filters paralleled on the input side. Figures 28 and 29 show to a larger scale the attenuation and phase shift characteristics of the sending and receiving filters, respectively, of channel 2, carrier frequency 540 p.p.s.

It is evident from these characteristics that the filters easily meet the general and particular requirements previously outlined. As regards the filter elements employed, the condensers are of a small mica-dielectric type, and the coils use a core of Permalloy dust material having a permeability of 110.

The aim in designing these coils was to find the minimum size and weight capable of providing the electrical properties determined by the filter requirements. Table IV gives a comparison between these coils and the coils used on the older system, both the new and old type coils having practically identical electrical characteristics.

TABLE IV

Comparison of Filter Retardation Coils

	Old Type	New Type
Core Material	Iron dust ($\mu=35$)	Permalloy dust ($\mu=110$)
Core Volume	5.4 in.^{3} = 88.5 cm.^{3}	.89 in.^{3} = 14.7 cm.^{3}
Panel area occupied	10.7 in.^{2} = 69.0 cm.^{2}	4.6 in.^{2} = 29.7 cm.^{2}
Height over terminals	4.56 in. = 11.6 cm.	3.0 in. = 7.6 cm.
Weight	4.0 lb. = 1.8 kgm.	0.87 lb. = 0.4 kgm.

Figure 30 is a representative curve for the variation of "Q," the ratio of reactance to resistance, with frequency, for the new type coils.

An Automatic Concentration Unit for Printing Telegraph Circuits*

By G. S. VERNAM

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SYNOPSIS:—*Where lightly loaded telegraph circuits terminate at a central telegraph office, they are usually grouped together on a switchboard or "Concentrator." The paper describes a Concentrator for start-stop printing telegraph circuits that uses step-by-step automatic switches and calling dials for establishing the connections. Certain special features are described, including a "Busy Position Locator" which enables a central office operator, upon calling a busy station, to locate the other operator's position which is in communication with the desired station, so as to forward the message to that operator, while the connection is maintained.*

Introduction

THIS paper describes a Concentration Unit for Printing Telegraph Circuits, which uses automatic switches of the step-by-step type, similar to those employed in certain dial telephone systems, for performing various switching operations.

Where a number of lightly loaded telegraph circuits terminate at a central telegraph office, and the number of messages over each circuit is insufficient to keep an operator fully employed, it is obviously desirable to group the circuits and to provide switching means so that a single operator at the central telegraph office can send and receive messages over any line of the group at will. Switching facilities for this purpose are usually called "Concentrators" or "Concentration Units."

Printers or "teletypewriters" of the so-called "start-stop" type are being used to a large and increasing extent on such lightly loaded circuits. They are used on lines connecting public branch offices of the telegraph companies within a metropolitan area with the main telegraph office, and are installed in offices of private customers of the telegraph companies to provide direct communication with the central telegraph office. As a result, concentration units are being used to an increasing extent for printing telegraph circuits.

Manually operated telegraph concentrators have been used for many years. They are usually small switchboards, with a jack and some form of calling signal for each line, and one or more cords associated with central office operators' telegraph sets or printers and adapted to be plugged into the jack of any line for the purpose of sending or receiving a message. In small installations, the jacks and signals may be mounted in small turrets placed within the reach of from one to four telegraph operators, so that they can make their own connections directly with the branch lines, but in larger installations the connections may be established by a separate switching operator stationed at a manual switchboard or concentrator. Such switchboards are commonly equipped for about 120 lines and arranged for use with a dozen or more central office telegraph sets or printers.

In another type of manual Concentration System[1], one or two 100-line turrets are provided for each printer operating table, the lines are multipled to the jacks on each turret, and a cord and plug is provided for each printer operator to directly establish connections from her printer to any desired line. This system requires a large number of jacks, a considerable amount of multiple cabling, etc., which tend to make the system expensive. Very ingenious methods have been used to reduce the cost of the equipment, however, including the use of special circuits that permit a one-conductor multiple and still provide the necessary busy test feature, etc., and

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*Presented at the Winter Convention of the American Institute of Electrical Engineers, New York, January, 1932.

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[1] See Wm. B. Blanton, "A Printing Telegraph Concentrator," A. I. E. E. Trans., June, 1931, Vol. 50, Page 414.

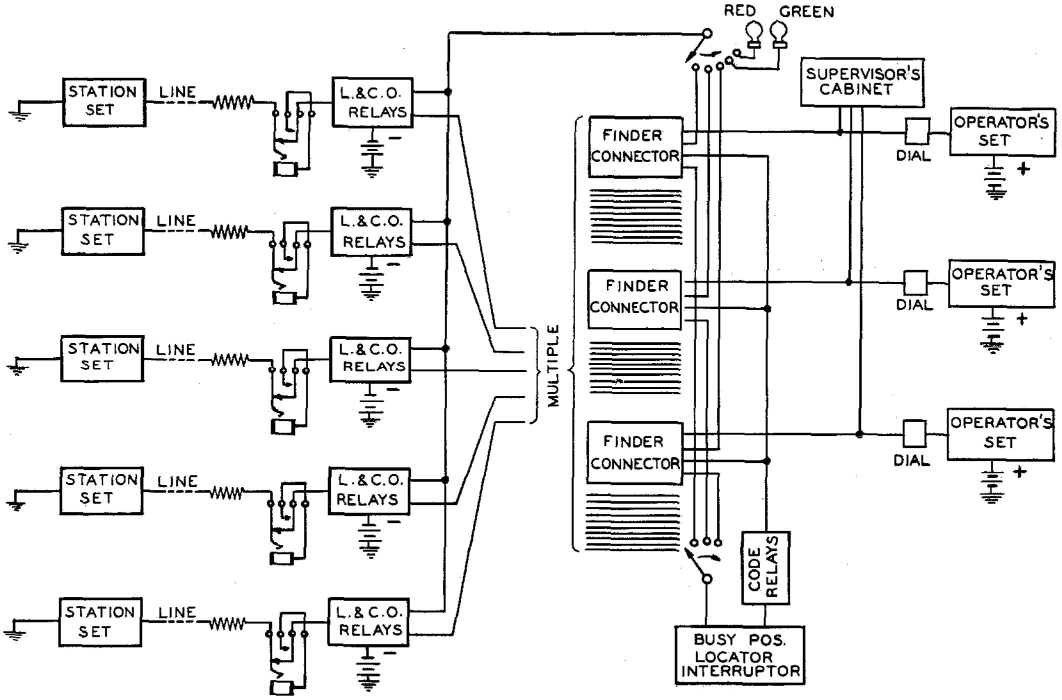

Figure 1—Schematic Diagram of Automatic Concentration Unit.

the use of studs in a moulded panel in place of the usual type of jack.

The Automatic Concentrator to be described is now being employed by the record communication companies of the International Telephone and Telegraph System[2] to permit the individual printer operators to set up their own connections by dialing for outward calls without requiring multiple turrets or switching operators and to permit inward calls to be established automatically to idle positions without the delay involved in manual switching operations.

To dial a branch station from the central office takes about four seconds, while inward calls from the branch stations are switched through automatically to idle central office operators in an average time of less than two seconds, and, as explained later, the branch station operator may start to send without waiting for a response or "go ahead" signal from the central office operator. About one second is required for releasing any connection. It is obvious that the switching operations are accomplished in much less time than with the manual system.

If idle operators are available, a single call will be switched through in about one second, but if two calls arrive at the same time, they will be connected to idle operators in succession and the second call may require two or three seconds. At rare intervals, three or more simultaneous calls may occur and require slightly longer time.

Because of the quicker switching, the central office operators spend a greater proportion of their time in actually sending and receiving messages, and our present limited experience with the system indicates that the number of messages handled per operator per hour is increased by about 20% as compared with that form of manual system in which a separate switching operator establishes the connections between the branch lines and the central office operators. This permits a corresponding reduction in central office printers and operators with a resultant saving in operating and equipment charges.

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[2] Postal Telegraph-Cable Company, The Commercial Cable Company, All America Cables, Inc., and Mackay Radio and Telegraph Co.

General Description of Automatic Concentration Unit

The Automatic Concentration Unit consists essentially of a group of step-by-step switches and relays, and certain auxiliary and supervisory equipment, including a Line Jack Panel, a Supervisor's Control Cabinet and a Busy Position Locator. This equipment is associated with a number of operators' printer sets in the central telegraph office, and a larger number of start-stop printers or teletypewriters installed in various offices usually within a metropolitan area, each such machine being connected over a single-wire line to the concentration unit at the central telegraph office.

The general arrangement of a system for not more than 100 lines is shown in Figure 1. Each branch station line extends through a resistor (for adjusting all lines to the same resistance), and a test jack to a pair of "line" and "cut-off" relays, which are multipled to the bank contact terminals of all of the step-by-step switches. When used for handling incoming calls from the branch stations, these step-by-step switches are called "line finders" as they serve to automatically find a calling line and connect it to an idle operator's position. When used for handling outgoing calls to the branch stations, the switches are called "connectors" as they connect the calling operator to the line corresponding to the number dialed. Concentration systems have been developed and installed, in which separate groups of switches were used for these two purposes, this arrangement being particularly suitable for cases where separate groups of operators are employed for handling inward and outward messages.

In the arrangement shown in Figure 1, however, the step-by-step switches are called "finder-connectors" because they combine in each switch the functions of both a "line finder" and a "connector," as each switch can handle calls in both directions. One finder-connector is associated with each central office operator's printer set and each operator is both an "inward" and an "outward" operator. Connections are also provided from each finder-connector to the "busy position locator" and to the lamps and keys of the supervisor's control cabinet. The switches are mounted in an enclosed rack of sectional construction, which is shown, with covers removed, in Figure 2.

Each central office operator's set is equipped with a dial unit, consisting of a metal case about four inches (10 cm.) square on which is mounted a calling dial, a three-position lever key and a small lamp used as a busy signal. This dial unit is mounted on the shelf of the printer table, to the right of the printer, as shown in Figure 3. In addition to the usual gumming desk, time stamp, numbering stamp, message boxes, etc., the printer table includes a push button type release key and two associated signal lamps, known respectively as the "hold" signal and "guard" signal. These are mounted in the table top back of the gumming desk, as shown in Figure 3.

The supervisor's control cabinet, see Figure 4, is mounted on the supervisor's desk, and is so located as to be visible to the supervisor from

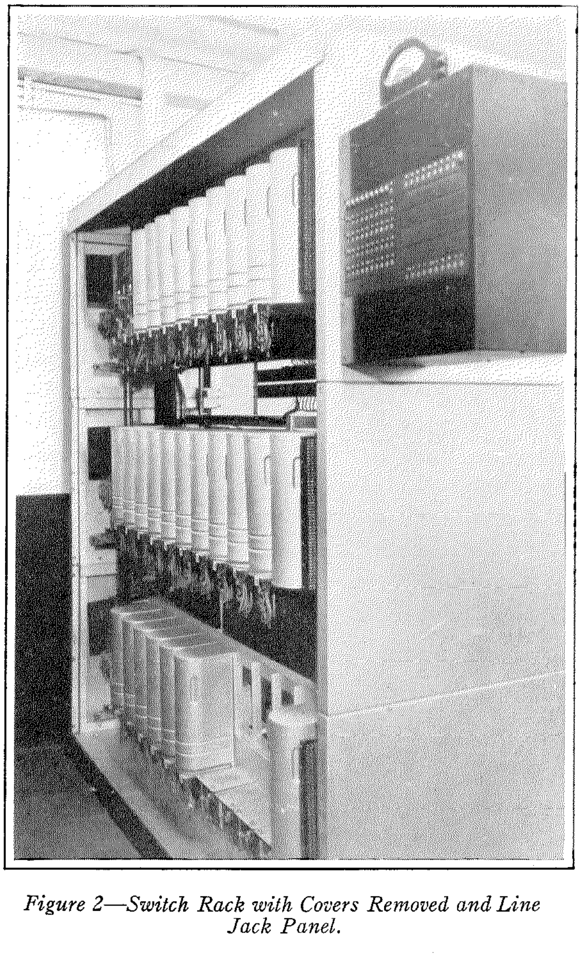

Figure 2—Switch Rack with Covers Removed and Line Jack Panel.

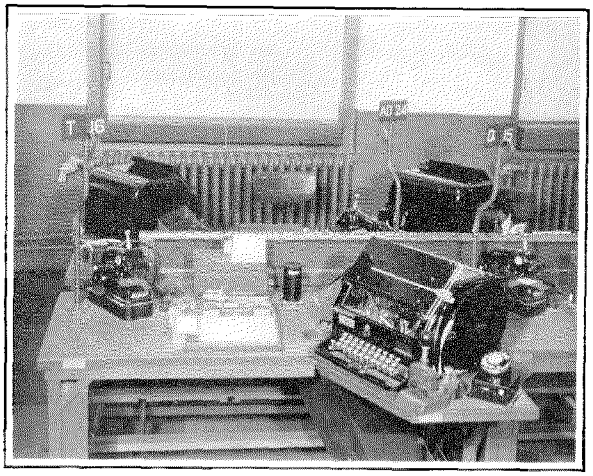

Figure 3—Central Office Printer Set.

almost any position near the operators' sets. This cabinet has a lamp and a key for each operator's set, known respectively as the "idle operator light" and the "make busy switch." Three electro-magnetically operated counters or service meters are also mounted in this turret. The lamps serve to keep the supervisor advised at all times as to how many operators are available for handling inward calls. The keys or "make busy switches" permit the supervisor to switch off any operator's position that is not covered by an operator, or that is to be used exclusively for sending, and thus prevent any incoming calls from being routed to such positions. The electro-magnetic counters may be used to determine the total number of inward, outward and busy calls during any given period.

In addition to the control cabinet, a standard, bearing a large green and a red lamp, is also mounted on the supervisor's desk. The green lamp lights when all operators' positions are "busy," i.e., actually busy and connected to a branch station, or made busy by the "make busy switches." The red lamp lights when there is an incoming call waiting with no idle positions to answer it. These lamps, together with the "idle operator lights," aid the supervisor in regulating the size of the staff so as to handle the messages efficiently and without delay, in spite of variations in the traffic load at different times. The location of the supervisor's control cabinet in relation to the operator's printer tables in a typical installation, is shown in the photograph, Figure 5.

The Line Jack Panel is mounted on the end of the switch rack (see Figure 2) and has a jack for each line. These jacks are used for testing the lines, measuring line current, etc. If a certain branch station is so busy during part of the day that it can keep a central office operator fully occupied in handling its messages, the branch station line can be "tabled," i.e., connected directly to a special central office printer set reserved for this purpose. A few extra jacks, associated with such sets, are provided in the Line Jack Panel, and lines to be "tabled" are connected to such jacks by cords with plugs on both ends. During light load periods, these cords are removed to re-connect such lines back onto the automatic switches. This arrangement decreases the number of automatic switches required, as it reduces the traffic handled through the switches during the busy hours.

The Busy Position Locator consists of a special sending device or interrupter, shown in Figure 6, which operates in conjunction with a rotary step-by-step switch and certain relays shown in the rear view of the switch rack, Figure 7. It serves to locate the operator who is connected with a busy branch station, as will be described later.

Operation of System

The general method of operation of the Automatic Concentration System may be best explained by following the operations that occur in handling typical outgoing and incoming messages.

Outgoing messages to be sent to the branch offices connected to the Concentration Unit are received from other sections of the central telegraph office. They will ordinarily be messages that have come in from distant parts of the country over long land lines, or from other countries by cable or radio. The number of the branch office is marked on the message by a routing clerk and the message is then handed to an idle printer operator. If several messages for the same branch office are received at about the same time, they will all be handed to the same operator for transmission. This operator first moves the handle of the lever key of her dial unit to the right. This lights the guard lamp on her table, extinguishes the "idle operator light" corresponding to her position on the supervisor's control cabinet, and makes her position "busy" to inward calls. She then dials the number of the branch office (two digits), which causes her finder-connector switch to select the terminals of the desired branch line, to test to determine if the line is busy, and if not, to connect the operator's set to the branch station line. After dialing, the operator glances at the "busy" lamp on her dial unit and restores her key to its normal central position. If the called line is busy, the lamp lights, and when the key is restored the busy position locator starts, as described later. On the other hand, if the called line is not busy, the light does not light, and restoring the key starts the printer motor at the branch station so that the operator may send the message or messages. After sending the message or messages and receiving an acknowledgment from the branch station, the operator depresses her release button, which stops the branch station motor, restores the finder-connector switch to its normal position, extinguishes her guard lamp and lights the "idle operator light" on the supervisor's control cabinet.

If a branch station has a message to send, the branch office operator operates a calling key on the printer set which starts the first idle finder-connector switch and causes it to automatically select and connect its associated operator's printer set with the calling line. While the switch is hunting for the calling line, it is controlled by a common group of relays, which cause the switch to step vertically until it reaches the proper level, and then to rotate until it reaches the terminals of the calling line, after which the common relays are released and serve to control another switch in handling succeeding calls. The guard lamp at the operator's position lights as soon as the finder-connector starts to find the calling line, and the corresponding "idle operator light" in the supervisor's cabinet is extinguished. The operator's dialing circuit is also disabled at this time so that she cannot interfere with the action of the switch by attempting to dial. As soon as the connection is switched through, which normally requires about one second, the motor at the calling station starts automatically. The calling station operator starts to send the message immediately without waiting for a response from the central office operator as the starting of the printer motor serves as a "go ahead" signal. When the message has been transmitted and acknowledged, the central office operator releases the connection in the same manner as for an outward call.

Circuit Features—Station Line Circuit

The circuits of the finder-connector switches are similar to those of step-by-step connectors used for telephone service, except for some changes of minor importance, such as the use of one instead of two wires for the line circuit, and the elimination of the usual ringing and talking battery circuits. These circuits are well known

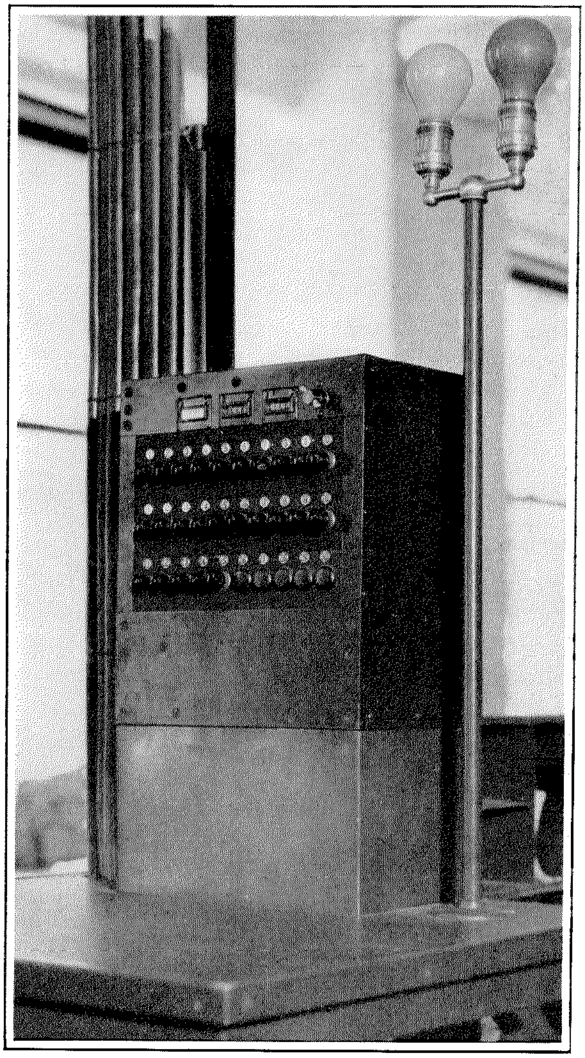

Figure 4—Supervisor's Control Cabinet.

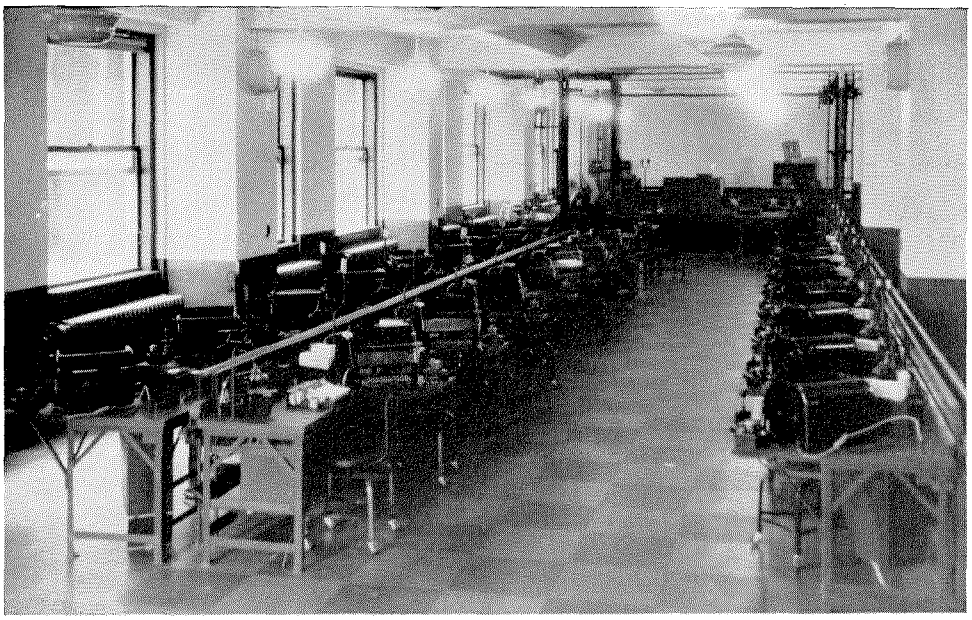

Figure 5—Typical Installation of Central Office Printer Sets.

and need not be described in detail. The circuits of certain other parts of the system may be of interest, however.

The circuit of the branch station printer set is shown in Figure 8. It should be understood that the line, shown at the top of the figure, normally extends from the branch station to the central office and through the line relay at the central office to the negative 110-volt power supply, while the station is idle. When the station is connected to a central office operator, however, the positive 110-volt supply is connected to the station line through the operator's printer. While the station is idle, the polar relay at the station is operated, as shown, and the high resistance winding of this relay reduces the line current to about 6 milliamperes.

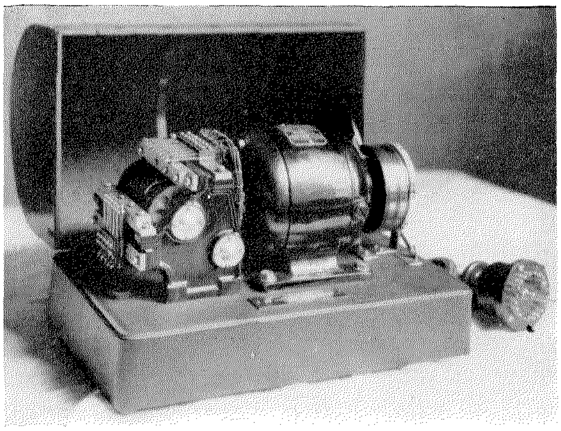

Figure 6—Busy Position Locator Interrupter.

To call, the branch station operator shunts this winding by operating the calling key and the line current increases to about 40 milliamperes to operate the line relay at the central office and to start the first idle finder-connector. When the call is switched through, positive potential from the operator's printer reverses the line current and releases the polar relay. The control relay now starts the printer motor and the branch station may send its message. Opening and closing the line in sending printer signals will have no effect on the polar relay.

In the case of calls from the central office, the positive potential applied to the line through the operator's printer, after dialing, reverses the line current and releases the polar relay. The control relay operates to start the motor, and it also short-circuits the high resistance winding of the polar relay to increase the current to its normal working value of about 60 milliamperes. In either case, the motor continues to run until negative potential is applied to the line when the central office operator releases the circuit.

This circuit permits controlling the station motor and printing over a single wire line. The low normal line current saves an appreciable amount of electrical energy where a considerable number of branch lines are connected to the system, as this current flows 24 hours per day, except that a larger current flows while the station is actually working. The motor can only start if the line is connected through to a central office operator (unless the line fails, which would be evident immediately by the action of the printer) as the only source of positive potential in the system is that connected to the operators' printers. It is, therefore, perfectly safe to use the motor start as a "go ahead" signal, which, together with the quick action of the automatic switches, provides very fast service in answering incoming calls. In the case of an outgoing call, the central office operator knows that if the line remains closed she has obtained a connection with the station, that the local power supply is intact at the station, and that the control relay has operated to start the motor and to shunt out the high resistance winding of the polar relay.

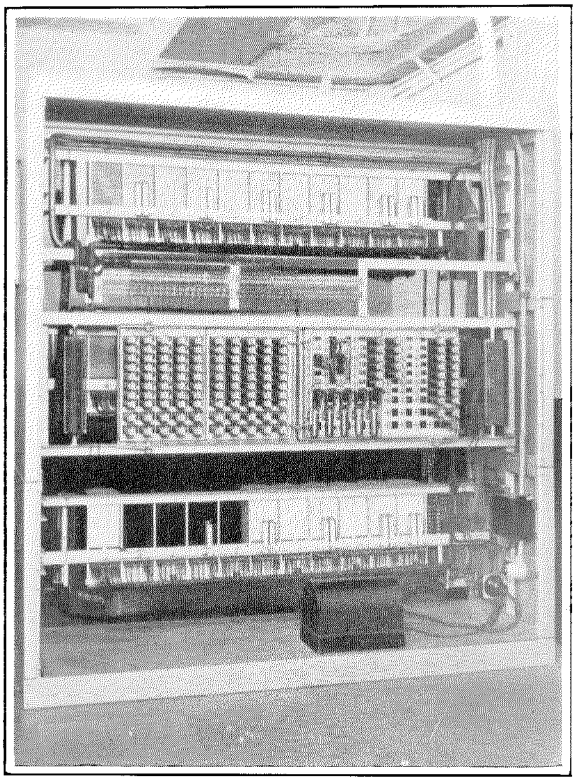

Figure 7—Switch Rack, Rear View With Covers Removed.

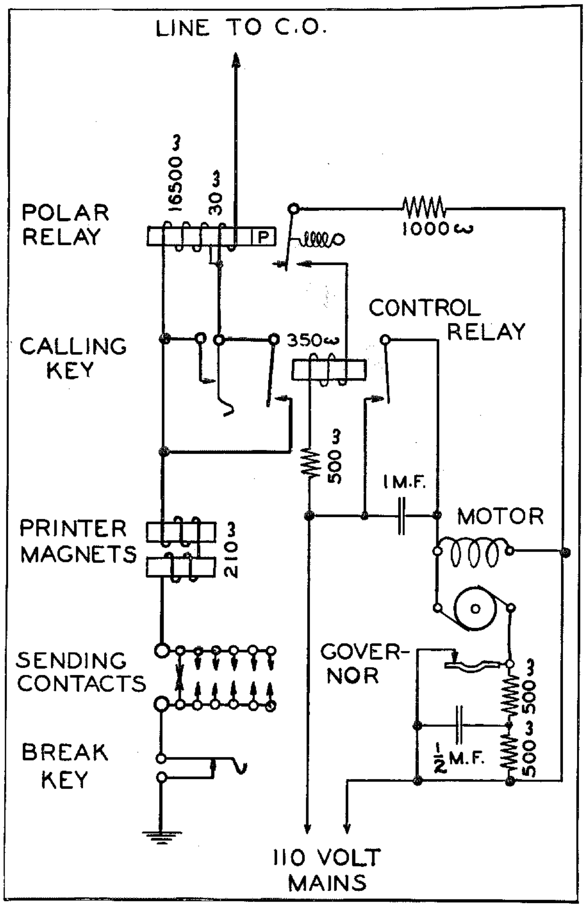

Figure 8—Station Printer Circuit.

Busy Position Locator

Messages handled through a Concentration Unit are of different classes, and it is necessary to give full rate messages precedence over reduced rate traffic, such as day letters and night letters. An operator calling a branch station to send a full rate message may find that station busy and thus be unable to obtain a connection with the station to send the message. It is not desirable to permit the operator to delay such messages, by holding them while repeated attempts are made to obtain a connection by dialing.

In all cases, when a line is found busy, it is connected with some other operator in the same central office. If it is possible for the calling operator to determine the number of the other position that is already in communication with the desired branch station, the message can be re-routed to this position and sent with but little delay. The purpose of the "Busy Position Locator" is to furnish the information for re-routing such messages.

When a calling operator dials a busy line, the "busy" lamp of her dial unit lights to notify her that the called station is busy. Her printer set becomes automatically associated with the "Busy Position Locator," which automatically finds the "busy" position that is already connected to the called line, and causes the "hold" lamp on that position to light. The interrupter of the busy position locator sends signals in the usual printer code representing the number of the "busy" position into the printer of the calling operator, which prints the number of the "busy" position. The printed record is in the form "–14–14–14," etc., and advises the calling operator to send the message to position No. 14 and to release the circuit. The "hold" lamp, which was lighted at the "busy" position, serves to notify that operator to hold the connection. The "hold" lamp is not extinguished until the connection to the branch station is released.

In order to accomplish these results, it is necessary to establish connections between the "busy position locator" and the finder-connector switches of the two operators concerned, i.e., the "busy" operator who is already in communication with the branch station and the "calling" operator who is attempting to call the same branch station. By means of these connections, the "hold" lamp is lighted at the "busy" position, the interrupter motor is started, and certain so-called "code relays" associated with the interrupter are operated to control the interrupter and cause it to send to the calling operator's printer signals corresponding to the number of the "busy" operator's position.

As the busy position locator interrupter is common to a large group of operators, and as two or more operators may dial busy lines at the same time, the circuit must be arranged so that it can respond to only one such busy call at a time in order to prevent false indications. For this reason, a rotary switch is provided to connect the interrupter to the calling operator's circuit. If two or more operators dial busy lines at the same time, the wipers of the rotary switch start and rotate until they reach terminals connected to the circuit of one of these calling operators, and then stop. The rotary switch, therefore, serves to connect the busy position locator to only one calling operator at a time.

After dialing a busy line, the finder-connector switch wipers of the "calling" operator are resting on terminals of the same line as those of the "busy" operator's finder-connector. An extra wiper, known as the "test" or "T" wiper, is provided on each switch, and this is associated with an extra set of bank contacts that are multipled to all switches. These wipers serve to establish a connection between the two finder-connectors for the purpose of operating the "hold" lamp and controlling the number signals to be transmitted by the interrupter, as described later.

The circuit of the busy position locator is shown in schematic form in Figure 9. In the drawing, the circuit has been modified slightly in order to simplify it. Only two finder-connectors are shown in the drawing, and the operating circuits of these have been omitted, and only the two relays of the switches that are concerned with the operation of the busy position locator are shown. The details of the 12 code relays have been omitted, as their action is obvious, but their location in the circuit has been indicated schematically.

The interrupter, shown in Figure 6, has a motor, equipped with a governor, which drives a cam drum at one-quarter of the usual printer operating speed, so that four character signals in printer code are transmitted during each revolution of the drum. This device has twelve contacts, which operate in a definite sequence. One of these contacts sends a figure shift signal, followed by a hyphen, and the so-called "stop" impulse for two more character signals. Another contact known as the "pick-up" contact, operates the control relays in such a way as to insure

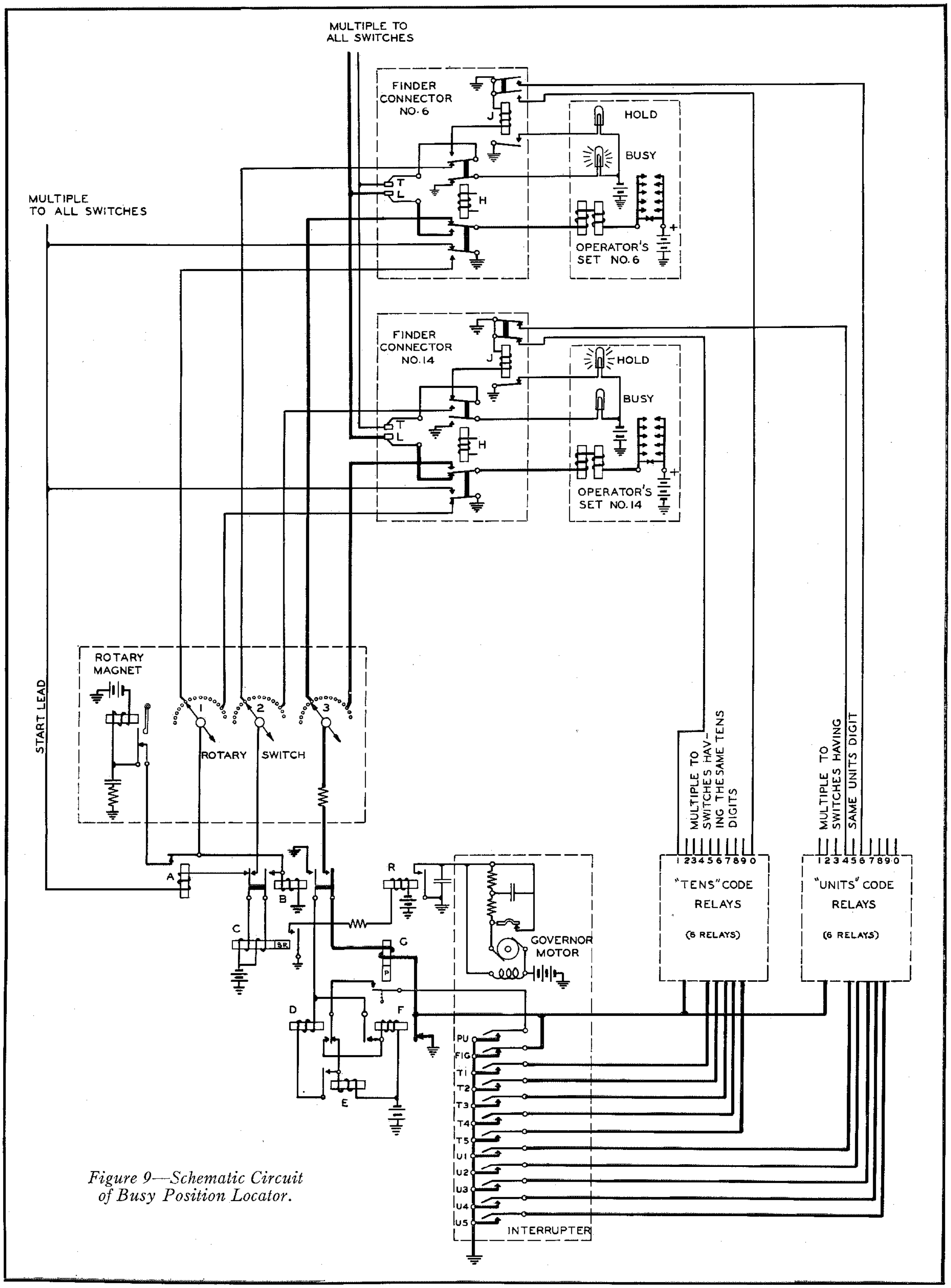

Figure 9—Schematic Circuit of Busy Position Locator.

that the transmitted signals always start with the figure shift signal. The other ten contacts send the individual selecting impulses of the two digits of the position number in the usual printer code. The circuits of these ten contacts are controlled by the tens and units code relays.

Assume that the operator at position 14 has obtained a connection with a certain branch station for either sending or receiving a message, and that the operator at position 6 subsequently dials the same station to send a message. Finder-connector switch No. 6 will advance to the terminals of the desired station, but, finding the line busy, will not close the line circuit through. Relay H of this switch will operate, as this relay is so connected that it always operates when the switch wipers rest on the terminals of a busy line. Relay H opens the sixth bank contact associated with the first wiper of the rotary switch and grounds the "start" lead, which operates relay A, and relay C. Relay C starts the interrupter motor and relay A causes the rotary magnet to operate intermittently and rotate the wipers until they reach the terminals associated with finder-connector No. 6. Relay B now operates in series with the rotary magnet. As relay B has a high resistance winding, the rotary magnet does not operate. Relay B locks itself through relay C, releases relay A, and closes the other two wiper circuits.

Battery from the left hand winding of relay C is now applied through wiper 2 of the rotary switch and the T wiper of finder-connector No. 6 to the bank wiring. As the wipers of finder-connector No. 14 are on the terminals of the same line, the J relay of that switch operates. This causes the "hold" lamp on position 14 to light, advising that operator to hold the connection for another message, and operates relays in the tens and units code groups to set up the printer code signals for "1" and "4" on interrupter contacts T1 to T5 and U1 to U5 respectively.

Relay B also closes the line circuit for operator's printer No. 6 through wiper 3 of the rotary switch and relay G to ground. Relay G operates and connects interrupter contact PU to relay E. The first time the PU contact closes, relay E operates and when the PU contact opens relay D operates in series with relay E. When the PU contact closes again (after a complete revolution of the cam drum) relay F operates, locks itself and removes the shunt to ground from the interrupter contacts and code relays, so that the signals "Figures," "–," "1," "4" are sent into printer No. 6, causing it to shift and record "–14–14–14" etc., advising operator No. 6 that the desired station is connected to position No. 14.

After noting this position number on the message, operator No. 6 releases the connection, restoring finder-connector No. 6 to normal and releasing its H relay as well as the J relay of switch No. 14. The "hold" lamp at position No. 14 remains lighted under the control of a locking relay that is not shown in the drawing. Relay H short-circuits relay B to release it and this, in turn, releases relays C, D, E, F and G, restoring the circuit to normal. If another operator has dialed a busy line in the meantime, relay A will operate immediately and relay C will remain operated to keep the motor running. It should be noted also, that relays D and E prevent any signals from being sent by the interrupter until the cam drum has made at least one complete revolution to get up to normal speed.

Modifications

The system providing for not more than 100 lines has been described, as it is simpler and has substantially the same equipment and features as a larger system. A system for 1,000 or more lines has been developed which uses additional automatic switches and auxiliary equipment in a manner somewhat similar to the use of this apparatus in automatic telephone systems.

A system using dials at each branch station and additional switching equipment at the central office has also been developed, so that any branch station can dial any other branch station and obtain a direct telegraph circuit to it through an automatically connected single line repeater at the central office. One indication is given at the originating office if the connection is completed and another if the called line is busy. The dial system also naturally provides for obtaining a printer connection to the central telegraph office or to various departments of the central office, such as to the cable division for sending cablegrams, to the land line message service division, to the radio telegraph division, or to a toll board for connection to distant cities.

Direct Printing Over Long Non-Loaded Submarine Telegraph Cables*

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SYNOPSIS:—*This paper describes a method for the electrical conversion of the non-uniform length combinations of the cable Morse Code into a modified five unit code and the application of this method to the operation of printers on long non-loaded submarine telegraph cables.*

NOTWITHSTANDING the rapid progress that has been made in recent years in the application of automatic printers to landline operation, and the continued efforts to apply similar methods to the operation of long non-loaded submarine cables, the siphon recorder, which requires manual translation, is still used almost exclusively in the operation of such circuits. While the recently developed loaded type of submarine cable possesses characteristics which permit of its being operated with a modified form of landline multiplex printing system, the numerous attempts to develop and apply a satisfactory direct printing system to non-loaded cables have not met with complete success. It is the purpose of this paper to outline briefly the various factors which enter into this problem and to describe a new type of cable printer which has been developed and placed in successful operation in the Commercial and All America cable systems.

The printing systems found satisfactory for landline operation employ uniform length codes in which all characters are composed of an equal number of current impulses, usually five. Although these systems might be modified to give satisfactory printing on submarine cables, the line time would be used so inefficiently as to make this procedure impracticable, and, furthermore, the equal length codes have the disadvantage that failures of individual pulses are not detectable in code traffic.

The high cost of long non-loaded cables in comparison with the signalling frequency which they are capable of transmitting, makes it necessary to use the shortest practical code. Although several codes have been proposed which are shorter than the cable Morse code as measured by the number of unit pulses of which they are formed, none requiring less average transmitting time per character than cable Morse code has been found entirely satisfactory.

In order to secure the advantage of direct printing without sacrificing cable capacity, it therefore appeared necessary to design either a new type of printer capable of operating on code combinations of varying length, or to devise an automatic means for converting signals received in cable Morse code into a uniform length code suitable for controlling printers of the type already developed for landline operation. The difficulties previously encountered in attempting to solve this problem by the former method were so serious as to discourage further efforts along these lines. The obvious means of solving the problem by the code transformation method, namely, designing a mechanical translator in which the received Morse code signals would select an element corresponding to each character, and this element in turn would set up the new code combinations for that character, was so cumbersome as to appear uninviting also.

The present solution of the problem resulted from the observation that when cable Morse code combinations of 1, 2, 3 or 4 units, each followed by a letter space of 1 zero unit, are expanded into five unit combinations by the addition of pulses opposite in polarity to the last pulse in the normal Morse combination, the 30 unequal length combinations of the Morse cable code are transformed into 30 distinct five unit combinations without duplications, thereby providing the basis for the use of five unit code printers. For example, the cable Morse combination for the letter "E" is one positive pulse followed by one zero pulse, which would be translated into one positive pulse followed by four negative pulses. The phrase "zero pulse" is here

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used to denote the condition of zero current or polarity for a unit interval of time. The cable Morse letter "A" comprises one positive pulse and one negative pulse followed by one zero pulse which would be translated into one positive pulse and one negative pulse followed by three positive pulses. The other cable code combinations are similarly translated into the five unit combinations shown in Figure 1, in which both the upper and lower case characters are shown. It should be noted that in the case of the letter "T" and certain other characters, the fundamental law of translation is not applied in the exact manner stated above. These deviations from the law were made to simplify the equipment and to facilitate the carrying out of certain standard Morse practices on the printers.

This general law of transformation as above stated is so simple that it was possible to devise a means for operating directly upon the electrical pulses of the Morse signals to accomplish the code transformation without the aid of complicated mechanical devices. The 30 combinations referred to take care of the letters of the alphabet, with a few combinations to spare. However, as more than 30 separate combinations are required to represent the alphabet, figures, punctuation marks, etc., the cable Morse code necessarily includes, in addition, a number of combinations of five units and a letter space. It is obvious that all of these five unit combinations will be found duplicated in the new five unit code into which the 1, 2, 3 and 4 unit cable Morse code combinations were expanded.

By employing case shifts according to the usual practice followed in landline printer operation, one set of meanings was assigned to the five unit combinations derived from the shorter cable Morse code characters, and another set of meanings to the normal five unit combinations of the Morse code which undergo no expansion. The latter combinations are assigned to upper case characters of the printer, and the operation of the shifting mechanism is determined in such cases by the presence of the fifth pulse in the received signals. After being shifted into the upper case, the printer will remain there until a word space or special unshift combination is received.

Of course, it would have been possible to expand all of the Morse combinations, including the five unit combinations, into a new six unit code, thereby avoiding the need for assigning two sets of meanings to the five unit combinations. The former method was chosen because it conformed more nearly with present landline practice.

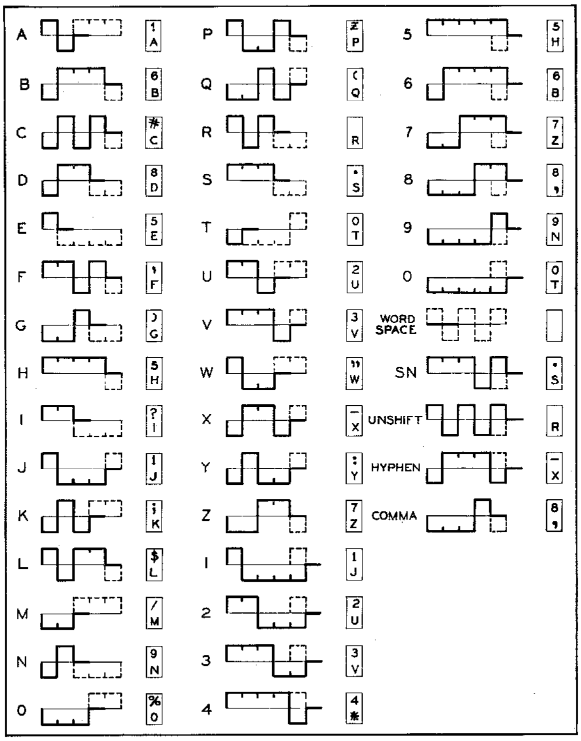

Figure 1

Continuation of the use of the cable Morse code, in addition to effecting economies in line time, has the advantage of requiring few, if any, changes in the relaying equipment now installed at repeater stations. It also permits the continuation of present operating and maintenance practices. For example, in order to economize line time, it is the practice, under certain conditions in sending figures, to use the so-called "short figures," i.e., A-1, U-2, E-5, D-8, N-9, T-0. A special arrangement of the translating mechanism makes it possible to continue this practice, providing the first figure in a figure group is transmitted as a long figure to cause the shift mechanism to operate.

When translating cable code signals from a siphon recorder slip, the operator can easily detect a dropped pulse at the beginning or at the end of a letter by the presence of an extra zero interval. The translating and printing mechanisms are so arranged that this extra zero will cause an asterisk to be printed as an indication of the error. A dropped pulse within a letter will result in two wrong letters being printed in place of the proper letter. This type of error is easily detected in ten letter code traffic because the word then has eleven letters.

An added pulse in place of a zero pulse usually results in a combination having five or more pulses which shifts the printer into the upper case and the last part of the word, therefore, appears as various punctuations and figures, indicating the error.

Less frequently, an extra pulse between two short letters will result in one wrong letter being printed in place of the two proper letters. This also is readily detected in ten letter code traffic as a nine letter word results.

Application of this printer to existing cables requires no changes to be made in the apparatus at the transmitting or repeater stations, the signals being transmitted by existing transmitters from perforated tape prepared on standard keyboard cable perforators. At the receiving end, however, the siphon recorder is replaced by a cable relay which operates the code translating and printing apparatus, comprising a distributor, maintained in synchronism with the received signals, a group of relays which perform the translating operations, and a slightly modified five unit code multiplex printer.

The function of the distributor is to regenerate the received signals and to control the operation of the local circuits associated with the translating relays and printer. As the Morse code characters contain a variable number of pulses, the first pulse of every character does not necessarily fall on a given segment of the distributor, as is the case when a uniform length code is used. It is therefore necessary to provide an auxiliary distributing device to direct the first and succeeding pulses of each character to the corresponding selector magnets of the printer.

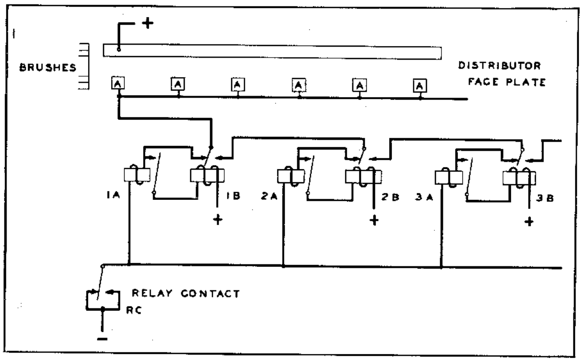

Figure 2

This auxiliary distributing device consists of a chain of counting relays as shown in Figure 2, in which the segments marked A of the synchronous receiving distributor are spaced at intervals corresponding to the time spacing of individual incoming pulses. The counting relays are arranged in pairs so that the first relay of the first pair is operated when the distributor brush passes over a local segment and the second relay of that pair is operated when the brush leaves the segment. When the brush passes over the next local segment, the first relay of the second pair is operated and when the brush leaves that segment the second relay of the second pair is operated, and in this way the relays will operate and lock up progressively as the brushes pass over the local segments. It will be noticed that when the brush passes on any segment after the chain of relays has been unlocked, a path for the current will always be completed through the winding of relay 1A. When relay 1A operates, a circuit will be completed from the tongue of relay 1A through the winding of relay 1B to positive potential, but no locking current will flow through relay 1B because it is short-circuited through the low resistance of the brushes. As soon as the brushes leave the segment, however, locking current for relays 1B and 1A in series will flow, thus operating relay 1B, which transfers the circuit from the local segments into the winding of relay 2A, so that when the brush passes over the next local segment, relays 2A and 2B will be operated in a similar manner to relays 1A and 1B. Relays 1B, 2B, 3B, etc., are provided with additional contacts, not shown in this figure, which serve to distribute the various selecting pulses into the proper paths. All of the relays of the distributing bank will be unlocked and restored to normal when the release contact RC is opened. The chain relay bank is arranged so that it will step along whenever impulses representing either dots or dashes are being received or when

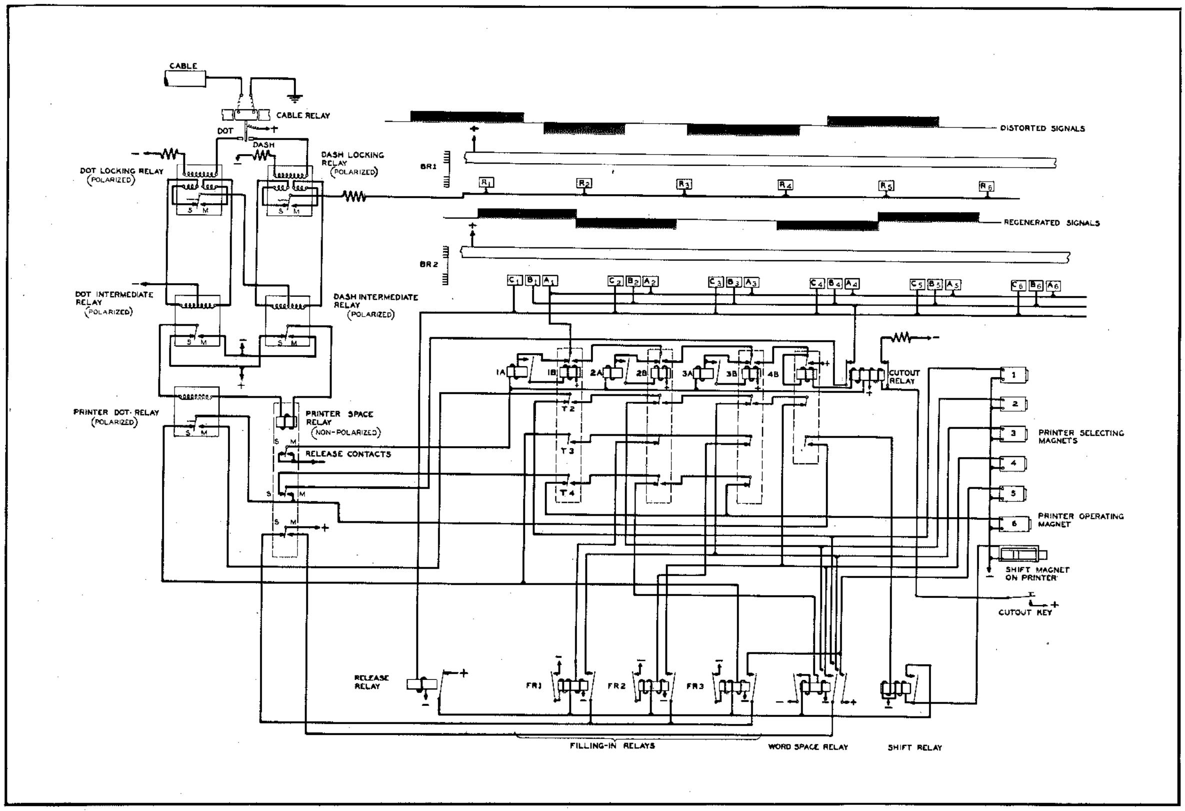

Figure 3

a group of zero pulses are being received, but it will be unlocked and re-set by the opening of the release contact RC whenever the incoming signal changes from a dot or dash to a zero pulse or from a zero pulse to a dot or a dash pulse.

The manner in which the counting relay chain is associated with the distributor and printer circuits to effect the translation and printing of cable code signals is shown in schematic form in Figure 3. The rotary distributor is provided with two segmented rings, one of which cooperates with the receiving relays to regenerate the incoming signals to their proper length. The other segmented ring serves to control the operation of the counting relay chain previously described, and the associated translating relays to effect the proper selection in the printer.

The pick-up segments R_1, R_2, etc., of the segmented ring, used for regeneration, are spaced at intervals corresponding to the length of the transmitted unit pulses, so that the time that the brush BR_1 takes to pass from one segment to a corresponding point on the next segment is equal to the time of transmission of one unit pulse. Thus, the regenerated signal is always restored to its full time length as originally transmitted. The brush BR_1 is caused to pass onto the segments R_1, R_2, etc., at approximately the middle of each received pulse through a synchronising means not shown here.

The groups of segments of the second segmented ring marked C, B and A are spaced approximately midway between the R segments of the first segmented ring. Thus, while the brush BR_1 is passing from one R segment to the next, the brush BR_2 is passing over one group of three segments. The passage of this brush over a "C" segment releases any "filling-in" relays that may have been previously locked up, in a manner to be described later. The passage of the brush over a "B" segment causes a circuit to be completed into one of the printer selector magnets, or into certain of the "filling-in" relays. The circuits to the "filling-in" relays are arranged so that the more pulses that are received in any given code combination the fewer will be the number of pulses to be filled in to the printer selecting magnets, the total of those received and those filled in being five.

The passage of the brush BR_2 over the "A" segments operates the counting relay chain as explained in connection with Figure 2.

The manner in which the regenerating and translating functions are carried out may best be understood from a detailed description of the successive operations involved in translating and printing a representative signal combination. The combination chosen, $+-0$, is the cable Morse code combination for the letter A. Referring to Figure 3, the regenerated pulses for the letter A are shown in their proper phase relations to the distributor segments.

The incoming signal is repeated in the normal manner by a standard cable relay into the operating winding of the dot locking or dash locking relay. The positions of the tongues of these two relays will be determined by position of the tongue of the cable relay when the brush BR_1 is *between* the pick-up segments R_1, R_2, etc. When the brush BR_1 passes onto any one of these segments, these locking relays are immediately locked and held in the positions they then occupy. Thus, in the reception of the combination $+-0$, the passage of brush BR_1 onto segment R_1 during the time the positive or dot pulse is being received locks the dot and dash locking relays in the positions corresponding to this pulse and moves the dot intermediate relay to the marking position. During the time that brush BR_1 is in contact with that segment, no movement of the locking relays can take place due to the greater strength of the locking current.

When the brush BR_1 passes off the segment R_1, the circuit to the intermediate relays is broken and they, being polarized, remain in the position last placed. The polarity of the regenerated signal is, therefore, determined by the polarity of the received signal at the *moment* the brush BR_1 passes onto the pick-up segment.

While the brush BR_1 is passing from segment R_1 to segment R_2 and the locking relays are again under the control of the cable relay, the brush BR_2 is passing over the segments C_1, B_1, A_1. During this interval, the intermediate relays are in the dot position and therefore the printer dot relay and printer space relay will both be on their marking contacts. When the brush BR_2 passes over segment C_1, the release relay will be operated and this in turn will release any of the filling-in relays which might have been in an operated position. All the relays of the counting bank will be in their unoperated position. When the brush BR_2 passes over segment B_1, a circuit will be completed from that segment through the contacts of the cut-out relay, which is normally in an operated position, through a contact of the printer space relay, through the tongue and marking contact of the printer dot relay, and through the tongue T_2 of relay 1B into printer selector magnet 1. This will trip the first code bar of the printer. The brush BR_2 now passes over segment A_1, and relays 1A and 1B of the counting bank will be operated and locked up in the manner previously described. During the time the brush BR_2 is passing between segments A_1 and C_2, the regenerated signal on the intermediate relays will change from a dot to a dash, and therefore the printer dot relay will return to its spacing position, while the printer space relay will remain operated. Brush BR_2 will now pass over segment C_2, thereby operating the release relay, but since all of the filling-in relays are in their unoperated position no change in the position of these relays will take place.

Brush BR_2 now passes over segment B_2 and the circuit is completed from segment B_2 via the cut-out relay contacts and the contacts of the printer space relay and printer dot relay through the operating winding of filling-in relay FR_3. Parallel circuits will also exist through the contacts of counting relays 1B, 2B and 3B through the operating winding of filling-in relays FR_1 and FR_2. All of the filling-in relays, therefore, are operated and lock up. Brush BR_2 now passes over the segment A_2 and relays 2A and 2B of the counting bank operate and lock up. During the time the brush BR_2 is passing between segments A_2 and C_3, the regenerated signal on the intermediate relays changes to zero and both the printer dot relay and the printer space relay will return to their unoperated position. Immediately after the lower tongue of the printer space relay reaches its spacing contact, a circuit will be completed from positive battery through that tongue and spacing contact to the right hand tongues of filling-in relays FR_1, FR_2 and

FR_3, and since these relays are all in an operated position, current will flow through printer selecting magnets 3, 4 and 5, thus completing the printer combination for the letter A, which, in the expanded five unit code, becomes $+-+++$. The printer space relay in moving to its spacing position also unlocked all of the relays of the counting bank which may have been operated. When the brush BR_2 passes over segment C_3, the release relay operates, thereby unlocking all the filling-in relays. The brush BR_2 now passes over segment B_3 and a circuit via the cut-out relay is completed through the tongue and spacing contact of the printer space relay, through tongue T_4 and spacing contact of counting relay 1B, and into the printer operating magnet, thus initiating the printing of the letter A. The foregoing illustrates in a general way the printing of any of the letters of the alphabet. When figures or punctuations are received, which consist of five or more pulses, the counting relay bank will be stepped up to its limit, and when the brush BR_2 passes over the B segment corresponding to the fifth impulse of the figure, a circuit will be completed from the B segment via the cut-out relay through the tongue and marking contact of the printer space relay, through the lower tongue and contact of counting relay 4B and through the operating winding of the shift relay which will operate and lock up and energise the printer shift magnet which will move the printer platen into the figures position. The operation, therefore, takes place prior to the reception of the zero pulse at the end of the code combination. The zero pulse then initiates the printing of the upper case character corresponding to the code combination.

A word space in the cable Morse code consists of two zero pulses, which, in conjunction with the zero pulse at the end of the previous letter, make a group of three zero pulses. Assume that the letter A, the printing of which has just been described, is followed by a word space. The first zero signal initiates the printing of the letter A, as previously described. When the second zero pulse is received, relays 1A and 1B of the counting bank will have been operated, and a circuit will have been completed from segment B_4 via the cut-out relay contacts, through the tongue and spacing contact of the printer space relay, through the tongue T_4 and marking contact of relay 1B, through the lower tongue and spacing contact of relay 2B, and through the operating winding of the word space relay. The word space relay will operate and lock up and trip printer selector magnets 1, 3 and 5, which is the printer combination for the word space. When the brush BR_2 passes over segment A_4, counting relays 2A and 2B will operate. When the brush reaches segment C_5, the release relay will be operated and this in turn will cut off the locking current from the word space relay which falls back and de-energises the printer selector magnets 1, 3 and 5. When the brush BR_2 passes over segment B_5, a circuit is completed via the cut-out relay through the tongue and spacing contact of the printer space relay, through the tongue T_4 and marking contacts of relay 1B, through the lower tongue and marking contact of relay 2B, through the lower tongue and spacing contact of relay 3B, and thence through the printer operating relay which initiates the word spacing functions of the printer. If the total zero interval received over the cable was only 2 units, it would be an indication of an error and the printer will, as previously explained, print a certain mark to indicate this. There being only 2 zero intervals, the regenerated signal on the intermediate relays will change from zero to a dot or dash while the word space relay is still in an operated position. The printer space relay will move to its marking contacts, thus completing a circuit from positive battery through the lower tongue and marking contact, through a tongue of the word space relay and through printer selector magnets 2 and 4. Printer selector magnets 1, 3 and 5 have already been tripped in anticipation of the word space, and the tripping in this manner of the rest of the printer selector magnets will result in the printing of an asterisk in place of the next letter, whatever it may be.

The purpose of the cut-out relay is to make it possible to prevent the operation of the printer during idle periods when synchronising pulses are being received. The type of signal chosen to keep the regenerative apparatus in synchronism during idle periods does not have sufficient spacing or marking pulses to step up the counting relay bank to its limit and therefore the cut-out relay, when once unlocked by short-circuiting

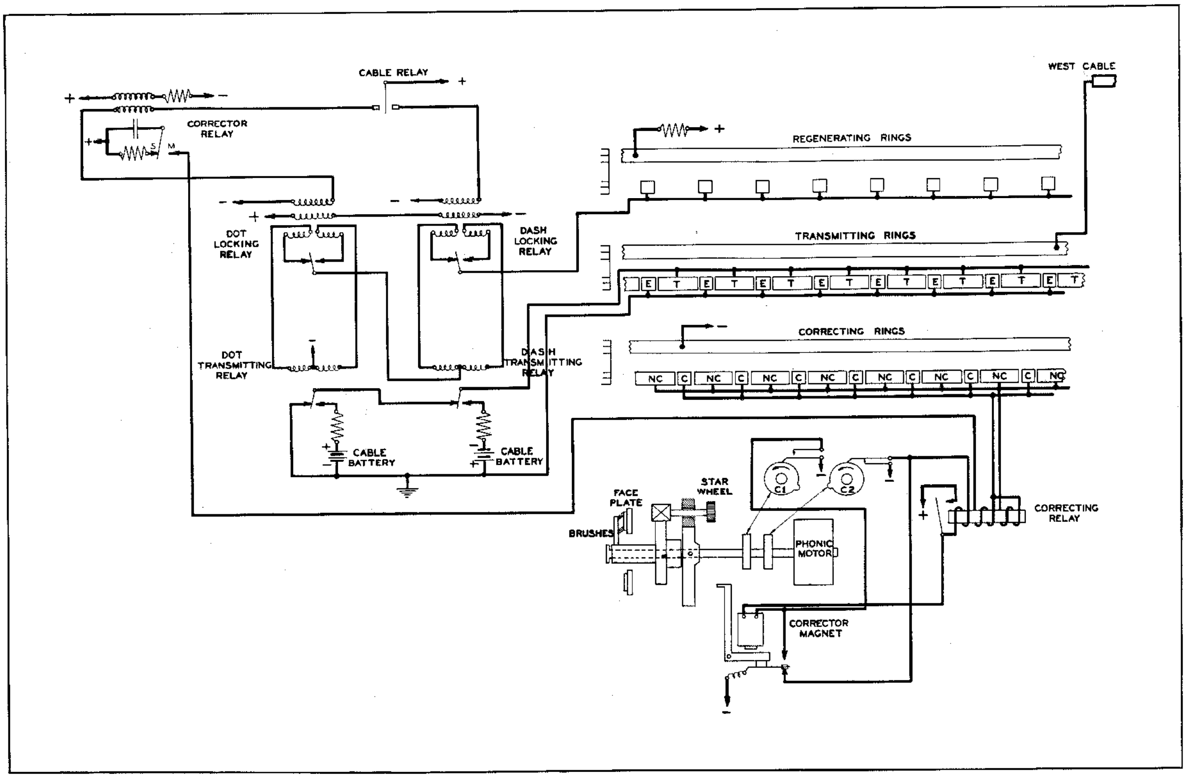

Figure 4

its winding through the depression of the cut-out key on the printer, will remain in its unoperated position until a long signal is received. The sending operator at the distant transmitter will precede the first message after a pause by a signal having five or more pulses in it, and this will automatically operate and lock up the cut-out relay again. During the time the cut-out relay is unlocked, the circuit from the B segments is open and therefore the printer will be unoperated.

Printers of this type have been placed in operation on two of the New York-London cable circuits of the Commercial Cable Company and on three of the All America Cable Company's cables to Central and South America. In the case of the installation made on the fastest Atlantic cable of the Commercial Cable Company, the speed of transmission was so much higher than the rate at which one operator could handle the received messages, that two channel operation was necessary. The terminal and regenerative repeater distributors were arranged for two channel operation, employing the method wherein individual pulses from each channel are alternated on the cable in a manner similar to that previously employed in certain multiplex systems and in channelling systems for ocean cables.

The type of regenerative repeater used at the intermediate stations on the cable route between London and New York is shown diagrammatically in Figure 4. Referring to that figure, the signals received over the east cable operate the cable relay, and this in turn controls the dot and dash locking relays and the dot and dash transmitting relays in conjunction with the regenerating rings on the distributor, so as to produce a regenerated cable signal on the transmitting relays. The operation of this regenerating circuit is identical with that already described in connection with the printer circuits in Figure 3, the dot and dash transmitting relays on Figure 4 being equivalent to the dot and dash intermediate relays in the other diagram. The contacts of the transmitting relays do not actually make or break any current, this being done by the transmitting rings of the distributor. The relationship between the brushes and the regenerating and transmitting rings is such that the transmitting relays will move only during the time the transmitting brush is making contact with an earthing segment "E." During the time the transmitting brush is on segments "T," the signals set up upon the transmitting relays are transmitted into the west cable. This arrangement eliminates any distortion of the outgoing signals which might be caused by the transmitting relays.

The correcting circuit which maintains the distributor in synchronism and phase with the received cable signals is also shown in Figure 4. The arrangement used is based on the Baudot system except that it has been modified to permit the correction to be generated from the cable signals instead of using line time for transmitting special correcting pulses.

The corrector relay will be actuated whenever the cable relay is on its dot contact. The condenser, which is connected to the tongue of the corrector relay, will be discharged when the corrector relay is on its spacing contact and will be charged when the tongue of the corrector relay moves over to its marking contact. The charge of this condenser will either operate or fail to operate the correcting relay depending upon whether the brush on the correcting rings is on a correcting segment marked "C" or on a non-correcting segment marked "NC." When the condenser charge occurs during the time the brush is on segment NC, the discharge passes through both windings of the correcting relay in such a direction that the currents through two windings are in opposition. The correcting relay when operated will lock itself up through its tongue and the contacts on cam C2 of the distributor. When cam C1 closes, the corrector magnet of the distributor will operate and lock up, and this will cause end A of the armature to engage with the starwheel on the distributor at a certain point in the revolution. Engagement of the armature with the starwheel will step back the brushes with respect to the motor approximately one degree. When cam C2 opens its contacts, the correcting relay will be unlocked and this relay in turn will de-energise the corrector magnet of the distributor. The speed of the phonic motor which is controlled by an electrically driven tuning fork is set so that the speed without correction will be a trifle too fast and this stepping back of the brushes from time to time will make the brush speed correct. A novel feature of this correcting circuit is that there is no point in the revolution of this distributor during which the correcting relay will fail to lock up if a correction is needed. If the correcting relay should attempt to operate during the brief interval that the contacts of cam C2 are open, a parallel circuit will be found through the back contact of the corrector magnet armature. An important feature of this correcting system is that it is not possible to step the brushes back more than once per revolution and this has been found to be of advantage in maintaining synchronism when a group of badly distorted signals are received.

This correcting system is also used on the distributors of the terminal sets which control the regenerating and printing operations.

This cable circuit contains five repeaters and is normally operating at a speed of 262 letters per minute per channel. Experience on this and the other circuits equipped with printers has shown a marked increase in the accuracy of reception due to the elimination of practically all human errors at the receiving stations, and has resulted in material staff economies.

Bibliography

H. H. Harrison, "Printing Telegraph Systems and Mechanisms," *Longmans Green and Company.*

J. W. Milnor, "Submarine Cable Telegraphy," *Journal A. I. E. E.*, 1922, Vol. 41, p. 20.

Herbert Angel, "Printing Telegraphs on Non-Loaded Ocean Cables," *Journal A. I. E. E.*, 1927, Vol. 46, p. 884.

H. H. Harrison, "Regenerative Telegraph Repeaters," *Electrician*, 1927, Vol. 98, pp. 8, 28 and 54.

A. A. Clokey, "Automatic Printing Equipment for Long Loaded Submarine Telegraph Cables," *Bell System Tech. Journal*, July, 1927, p. 402.

R. Appleyard, "Modern Atlantic Cable Operation," *Elec. Review*, 1928, Vol. 102, p. 715.

I. S. Coggeshall, "Submarine Telegraphy in the Post-War Decade," *Journal A. I. E. E.*, 1930, Vol. 49, No. 2, p. 476.

Balancing Cables by Inductive Networks

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EDITOR'S NOTE:—*At the suggestion of the Commercial Cable Company, Professor Pupin, while retained in a consulting capacity by that Company, investigated the possibilities of increasing the transmission speed of its heavy cable between Canso, Nova Scotia, and the Azores. The results of this investigation, in which engineers of the Commercial Cable Company co-operated, and the artificial balancing networks which were designed in accordance with a theory developed for the purpose, are described in the following paper, reprinted from "Electrical Engineering," Volume 50, No. 12, December, 1931.*

ELECTRICAL BALANCING of submarine cables by a network of conductors for purposes of duplex telegraphy is an old art. As long as these cables had a fairly high resistance, as they did in earlier years, their signaling speed was necessarily low. Under these conditions a satisfactory balancing network, the well known artificial line, consisted of resistances connected in series, and capacitances connected from ground to each junction of two consecutive resistances. This network was the equivalent of a sectional conductor, each section having resistance and capacitance, but no inductance; electrical reactions of the network imitated the electrical reactions of the cable. At low signaling speed such a network gave satisfactory results when its sections were sufficiently small and when a sufficiently large number of sections was used.

In recent years long submarine telegraph cables of low resistance have been laid for the purpose of increasing the speed of signaling. The heavy cable laid eight years ago by the Commercial Cable Company between Canso, Nova Scotia, and the Azores has a resistance of only about one ohm per nautical mile; it was intended to transmit at the rate of 600 letters per minute. At this speed, however, the inductance reaction of the cable came into play and the old balancing network containing no inductance in its sections could not balance it. In duplex working this heavy cable had to be operated at a much lower speed to accommodate the non-inductive balancing network. The design of an efficient inductive network thus became a very important problem in the operations of this long low-resistance cable.

Earlier Inductive Networks

Even a superficial study of this problem made obvious the fact that the old balancing artificial line had to be changed by introducing in its sections suitable inductive elements in place of the simple resistances. It was obvious also that within a certain frequency interval the effective inductance and resistance of these elements must vary with frequency, simulating the variations of effective inductance and resistance of the corresponding sections of submarine telegraph cable which was to be balanced. This seemed to introduce into the problem an insurmountable difficulty.

Breisig (*Electrotechnische Zeitschrift*, November 1899) and, twenty years later, Pernot (*Journal Franklin Institute*, September 1920; *British Patent Specification*, 1922) discovered that the effective inductance and resistance of a submarine cable section vary with frequency somewhat like the effective inductance and resistance of the primary of a transformer with its secondary short circuited. This discovery led to several attempts to imitate in the balancing network the electrical reactions of a cable by inserting in the sections of the old artificial line, transformers with short-circuited secondaries or their equivalent, that is, inductance short circuited by a non-inductive resistance or by another inductance. The most noteworthy among these attempts were those of Murihead Company and Davis (*British Patent Specification* 216,219, March 24, 1924) and of Gilbert (*U. S. Patent*, 1,533,178, April 1925). No results ever have been published which show how these applications of the old ideas of Breisig and Pernot succeeded in practise. It will be shown presently, however, that these applications cannot lead to a satisfactory balancing network since each section in such a network must be free from external electromagnetic disturbances. This means that the network inductances must have no stray fields in order to avoid mutual induction with the inductances in adjacent sections and with other external circuits.

Murihead Company and Davis, as well as Gilbert and others, not only overlooked this important provision, but, moreover, they *recommended* inductances with stray fields; the theory which they followed is not applicable to their structures since they invariably employed inductive elements having mutual induction not only with external circuits but also between sections of their networks. No mathematical theory of such networks exists, and just what are the determining factors in their design, is not clear.

Inductive Network with No External Field

In the following paragraphs will be discussed inductive networks having in their sections inductance coils with no external magnetic fields. In such networks the sections have no mutual induction with each other nor with external circuits; they are, therefore, free from external electromagnetic disturbances.

In a submarine cable which already is laid, the only quantities that can be measured are its terminal reactance and resistance at various frequencies. These measurements were made on a typical cable and formed the foundation of the study discussed here.

Curves *A* and *B* of Figure 1 represent at various frequencies the effective terminal resistance a_f and the effective terminal reactance b_f of a cable as determined by wheatstone bridge measurements. The cable is one belonging to the Commercial Cable Company and connects Far Rockaway, Long Island, with Canso, Nova Scotia. Its constants are

Length.......... $l = 974.33$ nautical miles
Average capacity $c = 0.384$ μf. per nautical mile
Average copper resistance....... $r = 2.45$ ohms per nautical mile

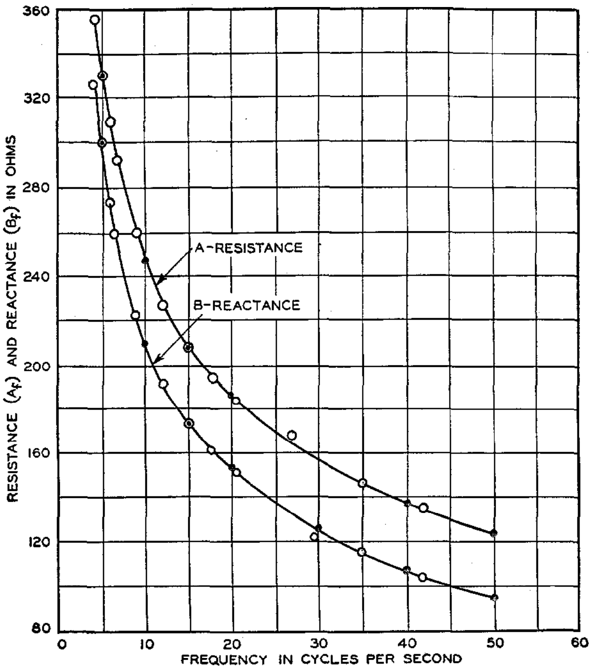

Figure 1—Effective Terminal Resistance (A) and Reactance (B) for a Typical Submarine Telegraph Cable (circles) and for the Inductive Network Designed to Balance it (dots).

Submarine cables are not of the same size at each point in their length; shore ends are much larger than deep sea parts, and hence the effective capacity and the effective inductance vary from point to point. The cable just referred to thus is not uniform, but a uniform cable which at all frequencies will have the same terminal reactance and resistance as this cable can be designated in theoretical studies; call it the *equivalent cable*. It can be specified as follows: Let C_f', R_f', and L_f' be the capacity, resistance, and inductance respectively per unit length of this equivalent cable at frequency f. Then if it is to have the same terminal reactances and resistances at various frequencies as those recorded in Figure 1

$$a_f - i\, b_f = \sqrt{\frac{L_f'}{C_f'} - \frac{i\, R_f'}{p\, C_f'}}$$

or

$$(a_f^2 - b_f^2)\, C_f' = L_f'\,;\; 2\, p\, a_f\, b_f\, C_f' = R_f' \qquad (1)$$

where $p = 2\,\pi f$

Make C_f' independent of the frequency and equal to 0.384 μ f., the same as the average capacity per unit length of the Far Rockaway-Canso cable. From eqs. 1 and curves A and B of Figure 1, the effective resistances R_f' and inductances L_f' of the equivalent cable were calculated. From these calculations curves A and B of Figure 2 were plotted for the frequency interval between 5 and 50 cycles per second.

An inductive network which can balance this equivalent cable obviously will balance also the original cable. Such a network will balance the equivalent cable at every frequency for which the effective inductance and resistance in its sections are the same as in the corresponding lengths of the cable. The aim of this study was to design a balancing network of this kind, employing in its sections inductance coils possessing no external fields. Several methods of construction were found to give very satisfactory results. The simplest of these is described here in some detail.

Network of Inductances in Series

The network discussed here employs in each of its sections two inductance coils connected in series as shown by coils 3 and 4 of Figure 3. Each coil is toroidal in shape and thus has no external magnetic field; one is shunted by a simple resistance R_1. The unshunted coil has inductance l_0 and resistance r_0. Let L be the inductance of coil 4 and R its resistance, without the shunting resistance R_1. Then it can be shown that at frequency $10\,s$, and with coil 4 shunted by resistance R_1, the effective inductance L_{10s} and the effective resistance R_{10s} of the two coils connected in series will be

$$L_{10s}=\frac{L\,(1-a)^2}{1+s^2\,a_0^2}+l_0;\quad R_{10s}=\frac{(a+s^2\,a_0^2)R_1}{1+s^2\,a_0^2}+r_0 \tag{2}$$

Where $a=\dfrac{R}{R+R_1}$ and $a_0=\dfrac{2\,\pi\times 10\,L}{R+R_1}$

At frequencies $10\,s=20$ and $10\,s=30$

$$L_{20}=\frac{L\,(1-a)^2}{1+4\,a_0^2}+l_0;\qquad R_{20}=\frac{(a+4\,a_0^2)\,R_1}{1+4\,a_0^2}+r_0$$

$$L_{30}=\frac{L\,(1-a)^2}{1+9\,a_0^2}+l_0;\qquad R_{30}=\frac{(a+9\,a_0^2)\,R_1}{1+9\,a_0^2}+r_0$$

Hence

$$\frac{L_{20}-L_{30}}{R_{30}-R_{20}}=\frac{L\,(1-a)}{R_1}=\frac{L}{R+R_1}=\frac{a_0}{2\,\pi\times 10} \tag{3}$$

As may be seen later eq. 3 has proved very useful in the theory of the design of inductive balancing networks.

If curves are plotted for L_{10s} and R_{10s}, the inductance and resistance curves given by eq. 3, then for the frequency interval from $10\,s=5$ to $10\,s=50$ the inductive network will balance the equivalent cable to the extent, only, that these curves coincide during that interval with curves A and B of Figure 2. The problem of this study is, therefore, to adjust the physical constants of coils 3 and 4 (Figure 3) so that within this frequency interval the curves for L_{10s} and R_{10s}, as given by eqs. 2 coincide as nearly as possible with curves A and B of Figure 2. The frequency interval between 5 and 50 cycles per second is considered here because it is the important interval at the signalling speeds of the cable under consideration, that is, 600 letters per minute.

Assume that these curves coincide at frequencies 20 and 30, and that each section of the inductive network represents ten nautical miles of the equivalent cable; then

$$\left.\begin{array}{l} 10\,L_{20}'=L_{20};\ 10\,L_{30}'=L_{30}\\ \text{and}\\ 10\,R_{20}'=R_{20};\ 10\,R_{30}'=R_{30}\end{array}\right\} \tag{4}$$

Under what conditions will these coincidences occur? It will be shown presently that equation

$$\frac{L_{20}-L_{30}}{R_{30}-R_{20}}=\frac{L_{20}'-L_{30}'}{R_{30}'-R_{20}'} \tag{5}$$

determines these conditions completely, because (see eq. 3) it assigns definite values to all of the physical constants in eq. 2. These constants are: a_0, l_0, R_1, R, r_0, and $a=R/(R+R_1)$. The assumptions (eq. 4) leading to eq. 5 are, therefore, the foundation for the procedure of designing the inductive network considered here.

The right-hand member of eq. 5 has, according to Figure 2, a definite numerical value equal to 1/109 approximately. The left-hand member of eq. 5 is equal to $a_0/(2\ \pi\times10)$ according to eq. 3. Hence

$$a_0=\frac{2\ \pi\times10}{109}=0.576$$

and

$$a_0^2=0.332$$

This constant a_0 in the equations of the inductance and resistance curves of the network is therefore fixed by experiment. The other constants in eqs. 2 also are definitely fixed by experiment as follows:

$$\frac{L_{20}-l_0}{L_{30}-l_0}=\frac{10\,L_{20}'-l_0}{10\,L_{30}'-l_0}=\frac{1+9\ a_0^2}{1+4\ a_0^2}$$

Whence $l_0=18.30$ mh.
Again from eq. 2

$$(1-a)^2L'=\frac{(10L_{20}'-l_0)\ (1+4\,a_0^2)}{L}=56.57\ \text{mh.}$$

Having selected a convenient value for L, the inductance of the shunted coil without R_1, the constant $a=R/(R+R_1)$ also is fixed. It is 0.387 when $L=0.15$ henrys. Since

$$1-a=\frac{R_1}{R+R_1}=\frac{R_1\ a_0}{2\ \pi\times10\,L}=0.613$$

$$R_1=\frac{2\ \pi\times10\,L\times0.613}{a_0}=10.0\ \text{ohms.}$$

$$R=\frac{a\ R_1}{1-a}=6.3\ \text{ohms}$$

$$r_0=10\ R_{20}'-\frac{(a+4\ a_0^2)\ R_1}{1+4\ a_0^2}=20.0\ \text{ohms}$$

If therefore the physical constants of the two inductance coils in the sections of the inductive network have the values which have been calculated by means of eq. 5, then the inductance and resistance values will be as indicated in eqs. 4. The question now arises as to how the effective inductance and resistance curves of the two structures compare at other frequencies. This comparison is obtained easily by substituting successively different values of frequency from $10\ s=5$ to $10\ s=50$ in the following equations:

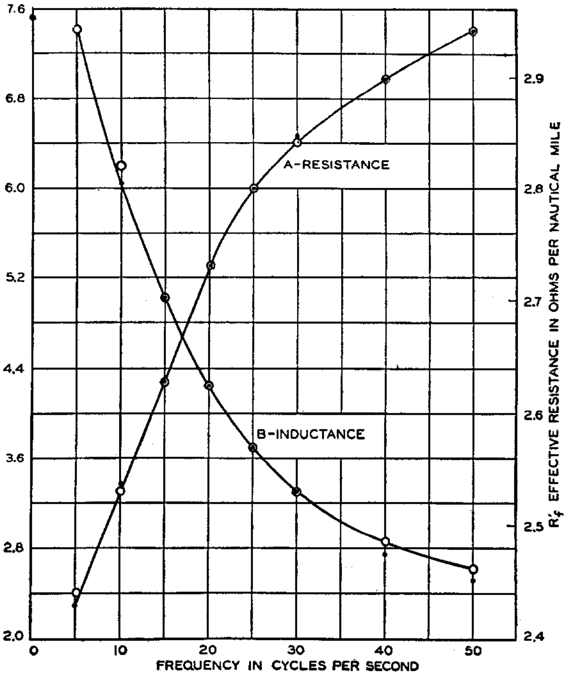

Figure 2—Effective Resistance (A) and Inductance (B) per Nautical Mile for "Equivalent" Cable (circles) and for the Network Designed to Balance it (dots).

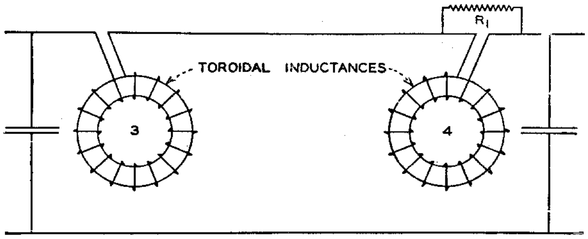

Figure 3—Schematic Diagram of a Section of Inductive Balancing Network With no External Magnetic Field.

$$\left.\begin{aligned} L_{10s}&=\frac{56.57}{1+0.332\ s^2}+18.3\\ R_{10s}&=20.0+\frac{(0.386+0.332\ s^2)\ 10}{1+0.332\ s^2}\end{aligned}\right\}\quad(6)$$

These equations are obtained by inserting in eqs. 2 the values of the constants just calculated.

The values of inductance and resistance thus calculated from eqs. 6 were plotted by dots in the curves of Figure 2. The overlapping of the effective inductance and resistance curves of the equivalent cable with those of the inductive network certainly is remarkable. However, the overlapping of the terminal reactance and resistance curves is even closer as is indicated by curves *A* and *B* of Figure 1. In these curves the small circles denote values determined by wheatstone bridge measurements on the cable and referred to previously, while the dots denote values calculated by eqs. 1 from L_{10s} recorded on curves *A* and *B* of Figure 2, and verified later experimentally by measurements on the inductive balancing network after this had been constructed.

Since the terminal impedance curves of the inductive network and of the equivalent cable coincide within the frequency interval between 5 and 50 cycles per second it follows that the network will balance the cable within that frequency interval. Practical operations are in complete agreement with this theoretical result. The same method of procedure was followed in the design and construction of inductive network balances of this type for other cable terminals, and in each case the result was just as satisfactory as in the case just described.

Modern Loading Equipment

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Editor's Note: *Conclusion of paper which appeared in the January,* 1932, *issue of Electrical Communication.*

Loading Coil Cases

THERE are four essential requirements for a loading coil case, namely, that access to the coils shall be solely electrical, that the coils shall be fully protected mechanically, that each circuit shall be isolated from every other and that there shall be an easy method of making connection between the coil conductors and the main cable conductors.

In addition to the above essentials, there are three desirable refinements; first, it should be possible to add more loading equipment at the same point without disturbing the existing loaded circuits; second, the equipment should be compact; third, there should be a reasonable degree of accessibility in the event of repairs becoming necessary.

The question of the best means of securing the above features is one which has received considerable attention and which at times has risen to controversy. Suggestions have ranged from encasing the coils in a form of entombed exchange-type repeating coil rack to inserting them under the main cable sheath during the application of the latter.

Experience has shown that the best manner of fulfilling all the requirements which have arisen or are likely to arise in Europe is to have available two types of loading case, one type intended for installation in a manhole and the other type for use directly in the ground. It is only in recent years that the last mentioned type of case has come to the fore since it was previously the almost invariable practice to install the case in some form of protected excavation, such as a suitable manhole, or even in a pipe full of sand.

The first type of case to be designed consisted of a cast iron container fitted with one or two auxiliary cables known as stub cables which provided the means of connection to the coils. Since this type of case was the forerunner of all others, it will be described first. The other type of case intended for direct burial possesses a jointing chamber in place of the stub cable and is usually referred to as a stubless case.

Before entering into a detailed description of the cases it should be noted that the designs now available are those which have had the benefit of manufacturing and installation experience under a variety of conditions. One of the most essential requirements for successful design is close co-operation with the installation groups.

Loading Coil Cases Fitted with Stub Cables

The cases with stub cables, as already mentioned, were designed for use in underground manholes, and the method of encasing the coils still holds in principle at the present day. Owing to the fact that the description of coils has been limited to the commencement of the period when the phantom circuit coil of a given type has the same overall diameter as the associated side circuit coils of the same type, it is apparent that so far as this paper is concerned, encasing methods which apply to coils also apply to 3 coil units.

Prior to the period of phantom and side circuit coils having equal diameters, it was necessary to stack the coils for each type of circuit in independent columns, for which reason the most economical shape of case from the space standpoint was roughly cylindrical.

The type of coil which comprises the unit referred to as the large iron dust cored unit was the first type having equal diameter coils for both side and phantom circuits. Its introduction simplified the selection of case ranges and to some extent, the manufacturing assembly.

The following paragraphs outline the method of assembly which applies generally to all the coils or units which have been under review.

The wound coils are first subjected to a drying and impregnating treatment in order to render them impervious to the agents which bring about insulation defects; they are then stacked coaxially upon rods made of wood or insulated metal known as dowels. Between each coil is placed an iron washer to isolate the coil both magnetically and electrostatically. This washer is particularly important in the case of units which are always stacked first with the phantom circuit coil followed by its pair of associated side circuit coils, then the phantom coil of the next unit and so on.

The dowelling process is carried out in a test room as distinct from carrying out tests in a factory operation room. Such a test room is shown in Figure 22, in which stacks of dowelled coils may be seen in the rack on the right, whilst coils in the process of selection lie on the bench to the left.

Interspersed with the dowelling operation is the fitting of the auxiliary cable forms used to make connection between the coils and the stub cable. These cable forms consist of identifiable insulated copper conductors laid up in a formation calculated to produce a minimum of interference between circuits. One or more such forms may be used depending upon the number of coils on the dowel.

Having built up a dowel with the necessary number of units or coils the complete stack is clamped firmly together by means of nuts at each end of the dowel rod. The completed dowel assembly is then subjected to further impregnation treatment and is inserted into a tubular iron canister, the free ends of the interconnecting quads projecting above the top of the canister which is then filled up with insulating compound.

The choice of a suitable insulating compound is not so simple as might be at first supposed since the requirements are somewhat comprehensive. It must have high insulating properties, it must not contract to any great extent upon cooling, it must not crack at the low temperatures encountered in ice covered ground, it must not become fluid at the temperatures met with in the tropics and, finally, it must not have any corrosive action upon the contents of the loading coil case. In spite of the stringency of the above requirements, it has been found possible to make a compound which gives a satisfactory performance on all points and which has given no indication of failure through a long period of use.

The compound sealed canister is what might be termed the unit of manufacture—that is, all later processes are concerned more with mechanical operations than with electrical adjustments. Since the stage of the completed canister as distinct from coil manufacture is the most desirable point for preventing the inclusion of faulty coils in the case, very exhaustive electrical tests are carried out on it.

The advantages of completing the unit of manufacture at the earliest possible stage in manufacture are manifold since the coils themselves are now protected against injury from the handling which they must undergo during the later stages. Furthermore, there will be no impairment of the insulation during storage under factory conditions, a factor which is of primary importance in the securing of flexibility of operation.

The next question is the choice of a suitable shape for the case. The cylindrical shape as used for the large iron dust cored unit cases is unsuitable from the standpoint of flexibility in case ranges when it is desired to cover a large number of units in one case. This difficulty was not encountered on the type of equipment just mentioned because the case had become too unwieldy to handle before the increase in diameter of the case coincided with a very large increase in the quantity of units which could be encased.

The above may perhaps be stated more clearly by taking actual dowel layups in cylindrical cases. Thus, the first range would be a single dowel case, then three dowels, next seven dowels grouped as a central dowel with six surrounding dowels and, finally, a nineteen dowel case grouped as one central dowel, six dowels around the centre and then twelve dowels around them.

Assuming that the maximum stacking height of a dowel is five units, the corresponding maximum capacities for the ranges quoted are 5 units, 15 units, 35 units, and 95 units respectively. The equivalent position with regard to a range of cases of square cross section is a first range of one dowel which may, of course, be cylindrical, a second range of four dowels, a

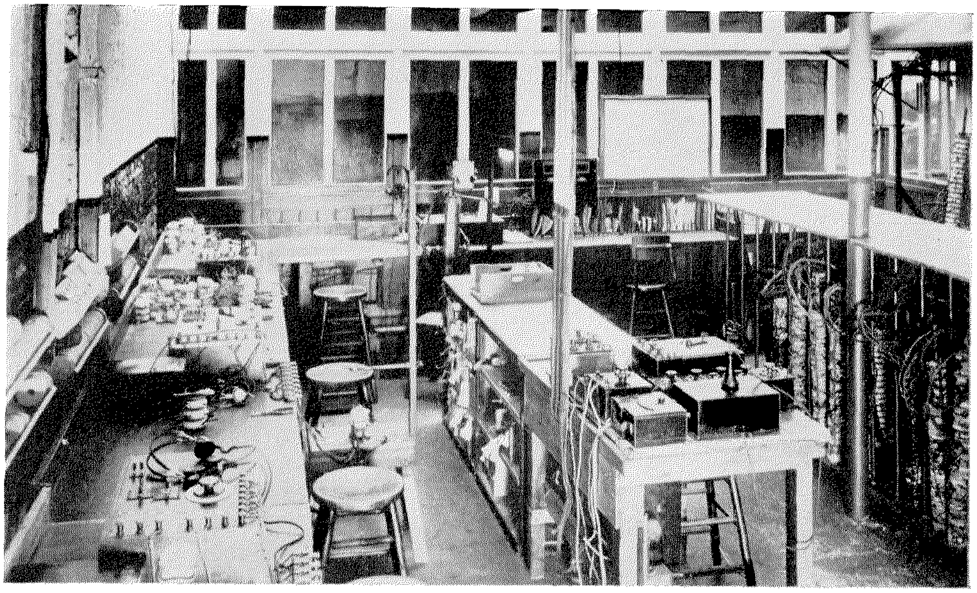


Figure 22—Dowel Assembly and Test Room.

third range of nine dowels and a final range of sixteen dowels, each case being set out in square formation.

Assuming again that the maximum height of case is five units, then the maximum capacities for each range are 5 units, 20 units, 45 units, and 80 units, respectively.

It will therefore be seen that the cases of square cross section give a better range distribution than those of cylindrical shape and this is most marked for cases containing more than twenty units, a condition which covers the majority of the cases required. Another point in favour of the use of the square cross section type of case is that the manhole space required for a case is the volume of the right prism of square cross section which will just contain the case. This volume is the same for a cylindrical case as for a square cross section case having a length of side equal to the diameter of the former.

For these reasons the inception of the small iron dust cored unit was accompanied by a change to the square cross section type of case, and since the maximum stacking height for the dowel was taken to be the height of 4 units, the maximum case content was 64 units, this being considered the largest case which could be conveniently handled.

The reduction in case dimensions occasioned by the use of the permalloy dust cored unit (Stanelec) enables eight units to be stacked on one dowel, thus permitting the construction of a case containing 128 units and having a mass of approximately three quarters that of the case containing 64 small iron dust cored units.

The number of units which may be contained in one case of the stub cable pattern is now no longer limited by its dimensions but depends instead upon the conductor content of the stub cables which will be described later.

Before passing on to the next stage of manufacture, there is one point regarding the location of units on the dowels which should be noted and that is the question of units for 4-wire circuits. When a case contains units for loading only 2-wire circuits there is no need to adopt any dowelling scheme other than that of straightforward stacking; when, however, the case contains units for 4-wire circuits or for both 4-wire and 2-wire circuits, it is desirable to separate the units which load 4-wire circuits in one direction from the units which load the 4-wire circuits operating in the opposite direction.

The degree of segregation required is insufficient to warrant any modifications to the normal case design as the separation of individual units resulting from the use of metal separating discs on the dowels, together with the canister wall, is sufficient for the purpose. Wherever possible, advantage is taken of the presence of units for 2-wire circuits by locating them at the point between the two groups of 4-wire circuit units. The auxiliary cables from a dowel of units for 4-wire circuits are always screened by means of metal foil or a braided metal sheath.

There is no necessity to screen 4-wire circuits from 2-wire circuits since the transmission level of the latter is approximately a mean between the levels of the two opposite directions of the 4-wire circuits, and the difference of level between a 2-wire circuit and a 4-wire circuit is never so great as that between two of the latter circuits.

When coils for music circuit loading are included in a case it is usual to confine them to one dowel, to space them apart by a distance equal to twice the axial height of a coil and to screen the auxiliary wiring.

Up to the present the cases have consisted simply of cast iron boxes having a case wall of from 13 to 23 millimetres in thickness depending upon the volume of the case, the iron being of a high quality with a very fine grain.

On the outside of the case, around the open end, there is a projecting flange through which holes are drilled for the fixing of the cover and the top surface of this flange is accurately machined to a smooth, level surface.

An air pressure test is carried out on the casting by clamping a temporary cover to the open end of the case, immersing the case in water and applying compressed air through a tube in the cover; the case has to withstand a pressure of 4.2 kilograms per square centimetre for a period of ten minutes. The case is then treated with a compound which makes it proof against any corrosive agent likely to be encountered after installation.

The next stage is the insertion of the canisters in the case after which it is filled with insulating compound until the tops of the canisters are

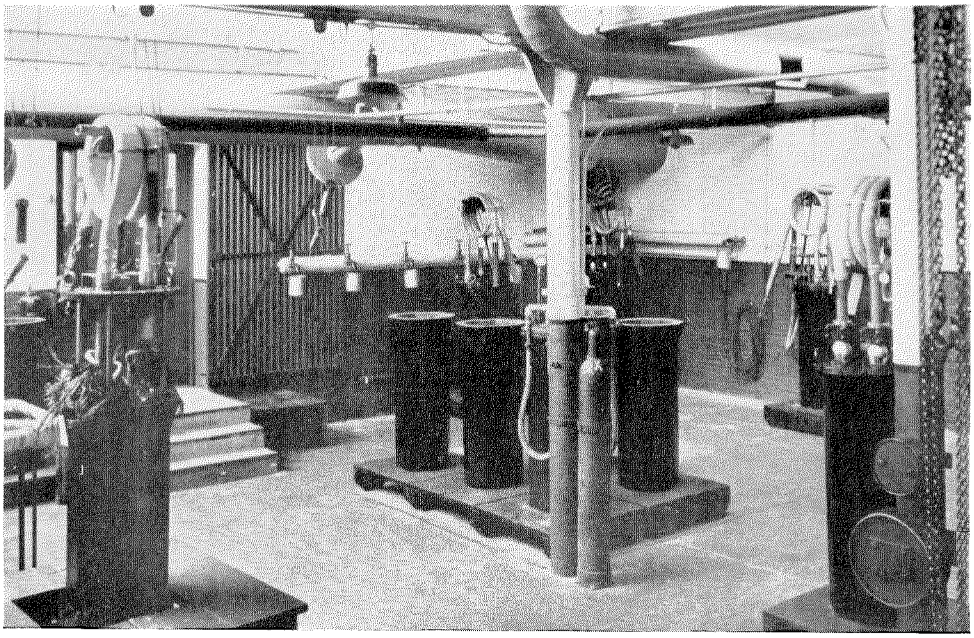


Figure 23—Case Assembly Room.

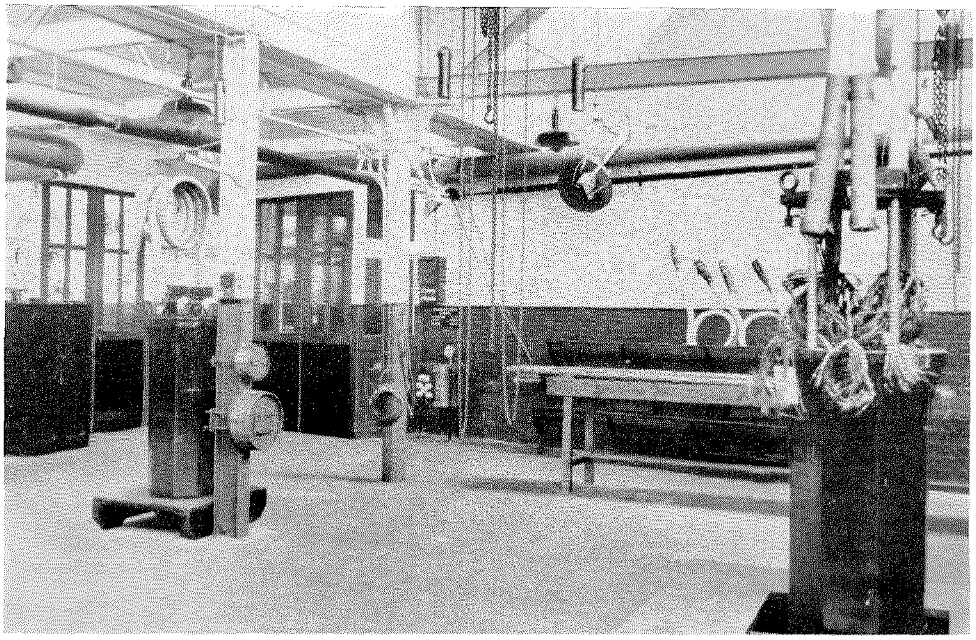


Figure 24—Case Assembly Room.

covered, the dowel cables being brought up through the surface of the compound.

After the preliminary filling the stub cable and cover are applied, the method used being to support the cover above the case flange at a height sufficient to give clearance for the jointing operation and then to pass the stub cable through a brass nipple which is screwed into the cover. A metal gasket is placed on the case flange for use in the sealing of the joint between case and cover.

The stub cable may be inserted before it is bent into position for packing or it may be bent prior to insertion.

Figures 23 and 24 show some special octagonal cases fitted with two stub cables in the course of construction; the metal drums on the ceiling supporting girders are for bending the stub cables whilst the large rosette shaped projections on the pipes near the roof are part of the air conditioning plant which maintains the temperature and humidity of the air in a suitable condition.

The armoured pipes suspended from the central column in Figure 23 are for applying compressed air to the case during pressure tests. Near the same column may be seen a gas cylinder containing nitrogen under pressure for use in drying the stub cables, from which it may be inferred that the equipment is not merely dry but is actually "tortured" to dryness. Against the wall in the background may be seen a number of taps attached to a steam heated pipe which is used for conveying the filling compound to the cases.

When the joints have been made the stub cable and wiring are pressed down inside the case and additional insulating material is applied at all points where contacts might occur.

More filling compound is then poured into the case to cover the joint and the end of the stub cable, whereupon the cover supports are removed and the cover is lowered down on the top of the case with the gasket intervening. The gasket has been previously coated with a sealing paste. The cover is then bolted down to the case flange by bolts passing through coincident holes in the flange and cover and which either pass through holes in the gasket or just clear the external rim of the gasket.

A lead joint is made between the stub cable sheath and the brass nipple in the cover. This joint which requires considerable operative skill in the making is not truly a plumber's "wiped" joint, although it is usually referred to as such.

The stub cable is clamped just above the nipple joint by means of a bracket which is permanently fixed to the cover. Having completely sealed the case and also temporarily sealed the free end of the stub cable, another air pressure test is applied through a small hole in the cover and if the case passes this test a sealing compound of bituminous composition is forced into the case until the space between the top of the original sealing compound and the cover is entirely filled.

The cover is recessed on the under side above the level of the gasket seal so that even if the latter is penetrated by moisture it has also to penetrate both the bitumen compound and the resinous compound before reaching any electrically vulnerable points. The filling vents in the cover are sealed by means of screw plugs. Electrical tests are carried out at various points during the course of the foregoing operations and when the cover has been finally sealed complete tests of all the electrical properties are carried out. Two views of a final test room are shown in Figures 25 and 26.

Finally, the stub cable end is closed by means of a lead seal and the cable is bound to a hoop type of support for protection during shipment.

The diagram, Figure 27, shows the construction of the type of case described above, whilst Figure 28 shows a case fitted with the temporary stub cable supports which are removed immediately prior to installation.

Since the stub cables are the part of the equipment which especially concerns the user from the viewpoint of handling, the following description may be of interest:

In the first place, it must be remembered that a stub cable has to withstand much more handling than the main cable with which it is to be associated since it not only has to be uncoiled from its packed position but it also may have to undergo considerable bending during installation or even after installation when it is desired to accommodate other cases in the same manhole. For these reasons the lead sheath is somewhat

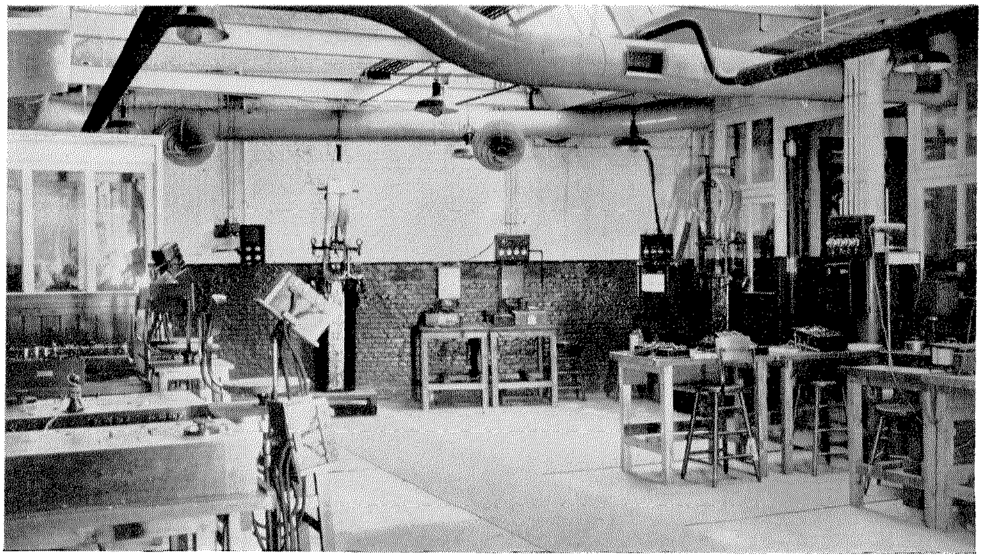


Figure 25—Final Test Room.

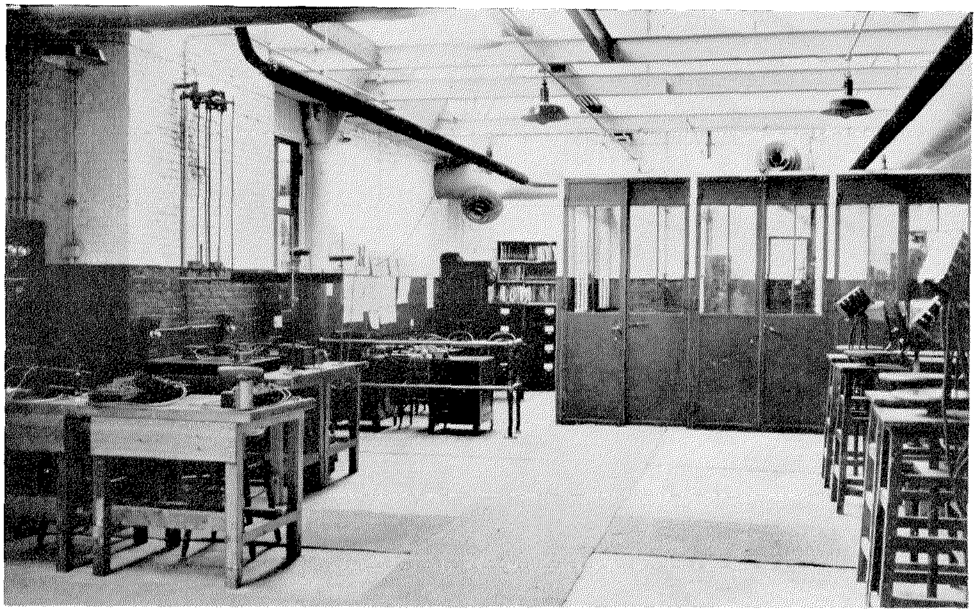


Figure 26—Final Test Room.

thicker than that of the main cable and is usually of the order of 3 millimetres. The best composition for the sheath has been found by experience to be an alloy of lead and antimony which is such as to give flexibility and at the same time maintain its inherent tensile properties in spite of being subjected to vibrations such as those due to nearby traffic.

The stub cables which are of the multiple-twin type have been standardised in lay-up and have the conductor contents given in Table I.

When the contents of the case do not exactly utilise all the conductors in the stub cable the unused quads are left isolated. If the case contains units for 4-wire circuits of opposite direction or if it contains music circuit coils, then a stub cable is selected such as will contain blank quads sufficient to provide segregation between the quads to the circuits in question and any other circuits which are considered prone to interference.

It will be seen above that the largest stub cable available contains 102 quads, a size which is considered the limit for a stub cable containing 0.9 millimetre diameter conductors. Any larger stub cable would be difficult to manipulate. By using 0.63 millimetre conductors it is possible to make a manageable stub cable containing 140 quads, but the difficulty of jointing such a conductor to the larger gauge conductor of the main cable has prevented the adoption of such a course.

It will be seen, therefore, that owing to the limitation in stub cable conductor content, the maximum number of units which may be encased in stub cable type cases are 51 units for a single stub case and 102 units for a double stub case, the corresponding figures for pair circuit coils being 102 coils and 204 coils, respectively. If the user of the equipment is willing to accept the 0.63 mm. conductors, it is of course possible to extend the above maxima to 70 and 140 units, or 140 and 280 coils in single and double stub cable cases, respectively.

Tables II and III give details of the various cases which have been standardised for the Stanelec units and coils for use on long distance cables.

TABLE I

Total Number of Quads in Stub Cable	Number of Quads in Centre	Number of Quads in 1st layer	Number of Quads in 2nd layer	Number of Quads in 3rd layer	Number of Quads in 4th layer	Number of Quads in 5th layer
7	1	6				
19	1	6	12			
24	2	8	14			
37	1	6	12	18		
44	2	8	14	20		
61	1	6	12	18	24	
80	4	10	16	22	28	
91	1	6	12	18	24	30
102	2	8	14	20	26	32

TABLE II
CASES WITH SQUARE HORIZONTAL CROSS SECTION

Code No. of Case	Code Letter		Maximum Capacity		Overall Dimensions Millimetres			Approximate weight with coils—Kilograms
	1 Stub	2 Stubs	Units	Coils	Height	Across Sides	Across Corners	
015	A	N	128	384	1240	540	620	684
015	B	O	112	336	1125	540	620	630
015	C	P	96	288	1010	540	620	576
015	D	Q	80	240	895	540	620	522
015	E	R	64	192	780	540	620	468
016	A	N	54	162	985	430	515	360
016	B	O	45	135	870	430	515	324
016	C	P	36	108	755	430	515	288
016	D	Q	27	81	640	430	515	252
017	A	N	16	48	715	340	390	162
017	B	O	12	36	600	340	390	144
017	C	P	8	24	485	340	390	126
017	D	Q	4	12	370	340	390	108

TABLE III
CYLINDRICAL CASES

Code No. of Case	Code Letter		Maximum Capacity		Overall Height milli-metres	Overall Diameter milli-metres	Approximate weight with coils—Kilograms
	1 Stub	2 Stubs	Units	Coils			
012	A	—	2	7	450	225	40
012	B	—	1	4	330	225	33

The design of cases for the small exchange area coils is essentially the same as that just described and is being extended to the use of a welded steel case as distinct from cast iron, but as the construction of the former is still in its initial stages the data on exchange area coil cases tabulated below is limited to cases constructed of cast iron.

As the exchange-area main cables are usually composed of small gauge conductors it is possible to use stub cables with 0.63 mm. conductors without interfering with the normal jointing practices.

It will be noted that cylindrical cases are again in evidence, the reason for this being that the coils are so small that this type of case has had to be associated with the square cross section type in order to extend the flexibility of the range.

For reasons already stated, the coils having inductance values in excess of 88 millihenrys have an increased axial height and two quantities are therefore quoted for each size of case. (Tables IV and V).

It should be remembered that the cases tabulated are standardised only because they have been found by experience to fulfill the usual loading requirements of main cables and that cases of special shape can be designed and constructed without unduly disturbing the normal manufacturing routine.

Instances arise occasionally where it is desirable to fit some form of protection to the stub cable and this is done by the use of flexible steel tubing which is slipped over the stub cable and fixed to the cover of the case by means of a flange which is bolted to a cylindrical box protecting the joint between the nipple and the stub cable. Such a construction is shown in Figure 29. Cases fitted with the above form of protection may be buried directly in the ground without fear of damage due to corrosion or of accidents in the course of later excavations.

In concluding this description of the stub cable type cases an enumeration of their advantages may be of interest.

The chief merit is probably that of being able to locate a case irrespective of the position of the main cable as it is possible to bend the stub cable within the limits required to make a suitable connection with the main cable, an advantage which is also apparent if it is desired to move the case in the manhole without disturbing the joint.

Another advantage is that the joint between the stub and main cables is of the normal cable type and the operators require no special instructions.

It is admitted that the stub cable presents a vulnerable point for accidents of a mechanical nature but, even so, the fault is usually identified and remedied before moisture has penetrated to the interior of the case.

Up to the present, approximately 20,000 of

TABLE IV

CASES WITH SQUARE HORIZONTAL CROSS SECTION

Maximum Capacity of Case Coils		Height to top of cover. Millimetres	Overall Length of Side Millimetres	Overall width across Corners Millimetres	Approximate weight with coils. Kilograms
Inductance above 88 millihenrys	Inductance of 88 millihenrys or less				
256	288	790	460	560	350
224	256	725	460	560	325
192	224	650	460	560	300
160	192	580	460	560	270
128	160	510	460	560	245
96	112	440	460	560	215

TABLE V

CYLINDRICAL CASES

Maximum Capacity of Case Coils		Height to top of cover. Millimetres	Overall Diameter. Millimetres	Approximate weight with coils Kilograms
Inductance above 88 millihenrys	Inductance of 88 millihenrys or less			
84	98	700	375	177
70	84	620	375	160
56	70	535	375	143
42	49	455	375	126
28	35	370	375	109
18	21	425	285	78
9	12	340	285	68
6	6	295	285	64

the above type cases have been installed in Europe, and approximately 0.1% of that number are returned each year for insulation or structural repairs.

Stubless Cases

Apart from a modification in the dowel cables the stubless case assembly is identical with that of the stub cable case up to the point where the cover is fitted.

The modification to the dowel cables consists of omitting any auxiliary conductors between the terminal wires of the coils and the conductors which are connected directly to the main cable; that is, the conductors which are connected to the coil terminal wires pass straight into the jointing chamber of the case. The method of connection eliminates any jointing in the case external to the canisters, thereby eliminating four conductor joints per coil and eight conductor joints per unit with a consequent saving of volume, time and vulnerable points.

In order to avoid a conglomeration of wires within the case, which would be detrimental from the crosstalk standpoint, the wiring is carried out by means of cables containing 18 quads which are laid up identically with the standardised stub cable of 19 quad capacity already mentioned except that there is a dummy centre and of course there is no metallic sheath. The case end of each cable is split into a number of sections equivalent to the number of dowels which can be accommodated by one complete cable. After the coils on the dowels have been wired to the cable the dowels are inserted in canisters and the latter filled with compound in the usual manner.

The groups of canisters with their associated cables are then placed in the cast iron case and each 18 quad cable is carried by means of an insulating framework to the centre at the top of the case after which the latter is filled with compound to within a short distance from the top.

The cover of the case is similar to that used for the stub type case except that the brass nipple is of a larger and heavier construction, having dimensions such as to accommodate all the 18 quad cables connected to the coils and having a thick flange midway between the top and the point where it enters the cast iron cover.

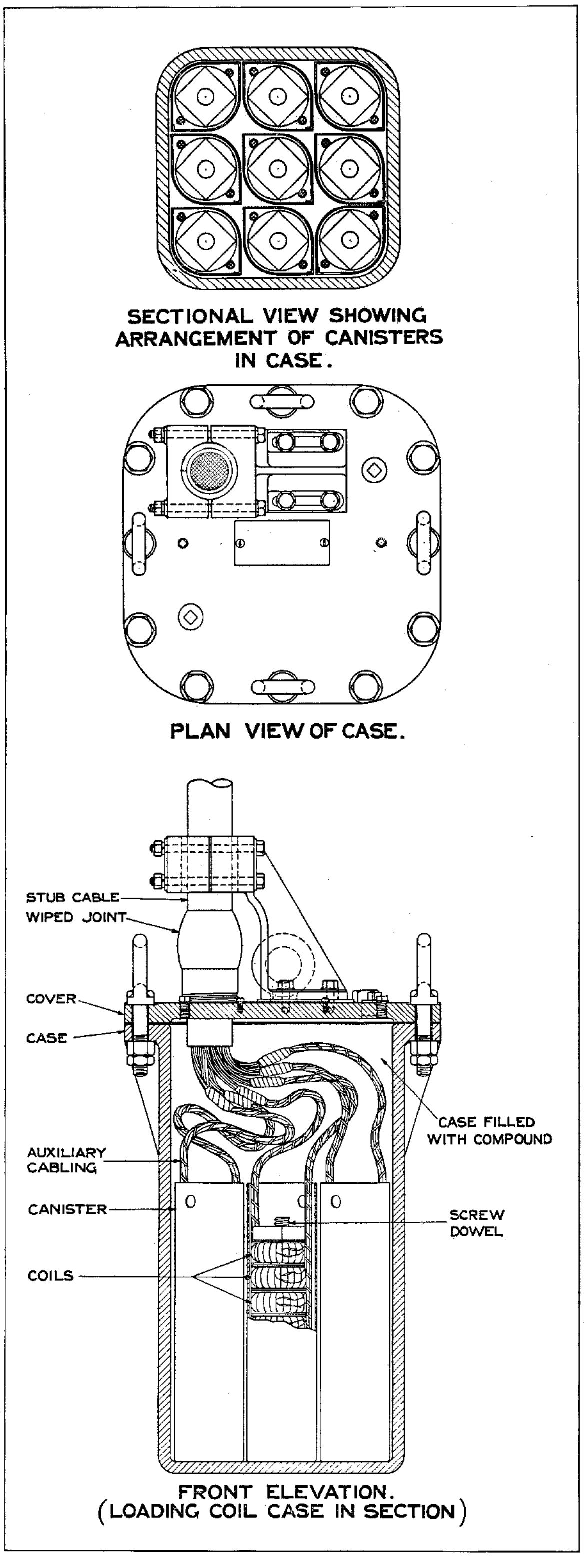

SECTIONAL VIEW SHOWING ARRANGEMENT OF CANISTERS IN CASE.
PLAN VIEW OF CASE.
STUB CABLE
WIPED JOINT
COVER
CASE
AUXILIARY CABLING
CANISTER
COILS
CASE FILLED WITH COMPOUND
SCREW DOWEL
FRONT ELEVATION. (LOADING COIL CASE IN SECTION)

Figure 27—Stub Cable Type Loading Coil Case.

The cover is bolted down to the top of the case with the normal gasket seal at the point of contact with the flange, the cables being brought out through the nipple which is forced into the cover by means of a taper screw and sealed.

When the cover has been sealed the cables are arranged in a suitable formation and bituminous compound is forced into the case through holes in the cover until the compound emerges at the top of the nipple, great care being taken to prevent the formation of vesicles. The filling holes and gas vents are then sealed with gas plugs.

In order to protect the cables during storage and shipment they are put into a sealed metal case which is lightly soldered to the flange on the nipple.

The method of installation is to remove the metal can and replace it by a formed lead sleeve shaped like an inverted isosceles triangle so that one corner has a hole which can be placed over the nipple with the rim resting on the flange whilst the holes at each of the other corners are in alignment with the main cable. This sleeve is in two sections so that the conductors in the case cables may be joined to the main cable conductors in the normal manner of a T splice, after which the sections are soldered together and wiped joints are made between the sleeve and the main cable along with the usual soldered joint between the nipple and the sleeve. It will thus be seen that all joints between the main cable and the case are of the lead seal type which experience has shown to be the most efficient for the purpose.

When the joint has been completed a cast iron protection cover constructed in sections is bolted to the case cover and clamped to the main cable which, under the conditions necessitating the use of a stubless case, is generally of the armoured type as distinct from the unarmoured cable running in a duct.

The construction of such a case is shown in Figure 30, whilst Figure 31 shows a completed case with the joint protection cover in position.

The most suitable shape of case is that having a rectangular horizontal cross section since by placing the longer side parallel with the cable trench a minimum amount of excavation is required although in certain instances a large base area may be desirable to counteract sinking or a shallow case may be required in order to avoid undue excavation in very hard ground.

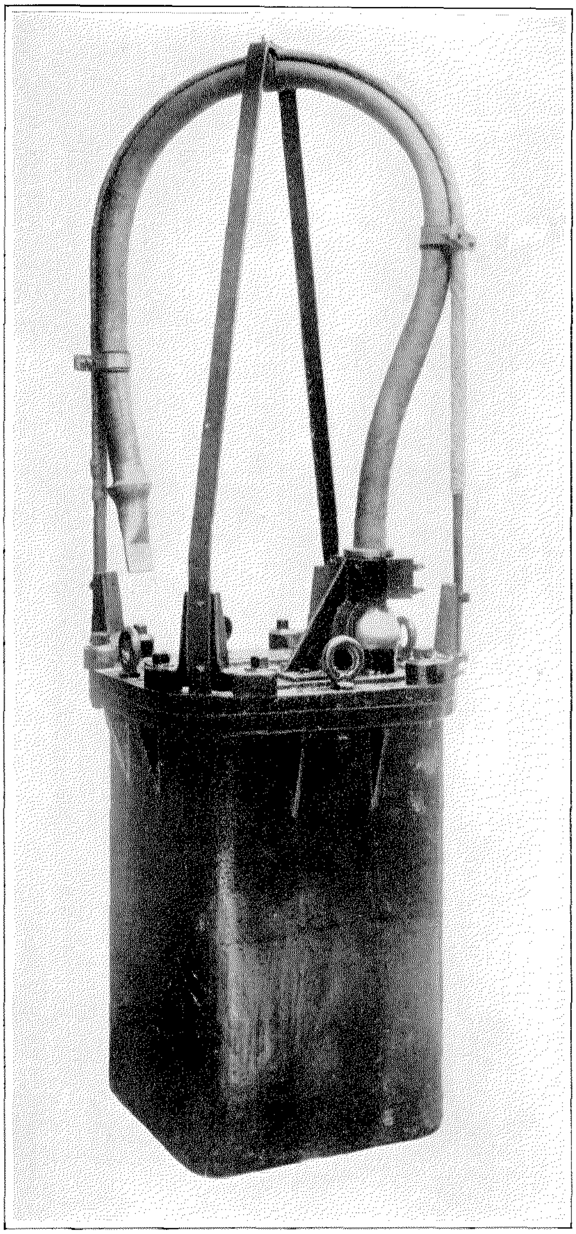


Figure 28—Stub Cable Type Loading Coil Case With Supports for Stub Cable During Shipment.

Table VI gives details of the dimensions of the cases which have been standardised but for the reasons just stated every facility is maintained for the production of designs peculiar to special conditions.

The chief advantage of the stubless type of

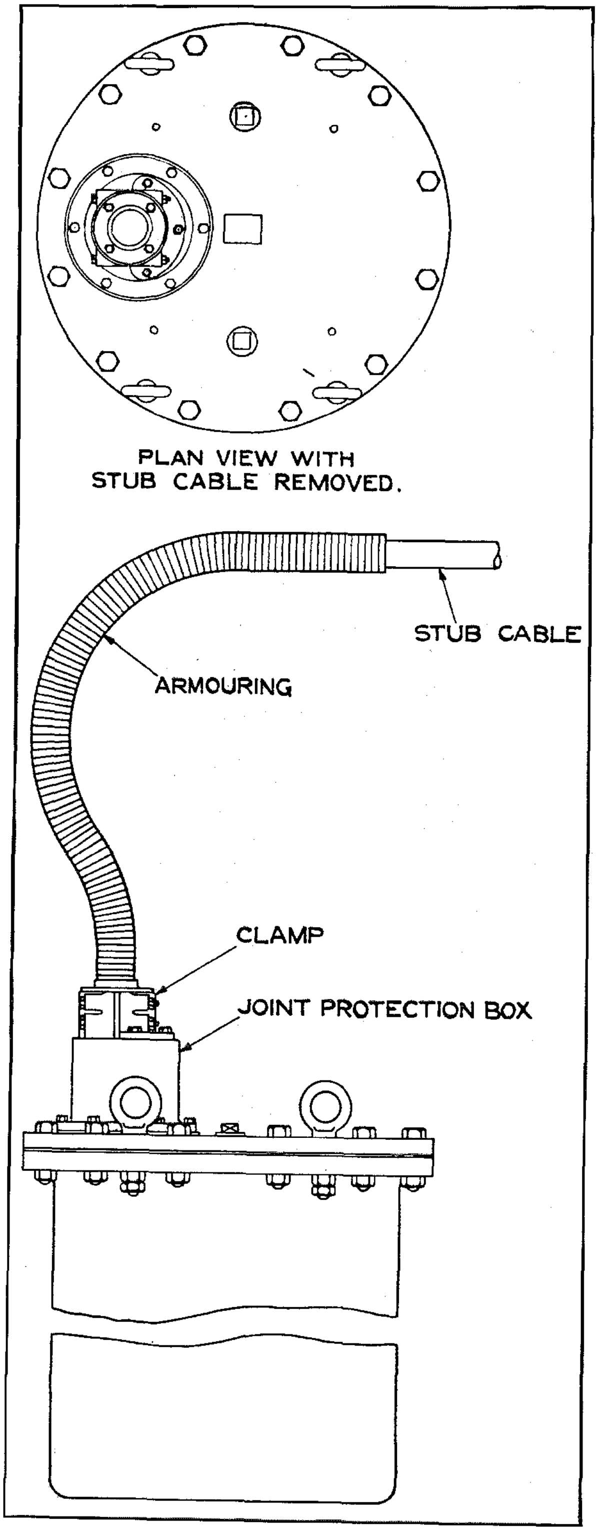


Figure 29—Method of Protecting a Stub Cable.

case is that it can be installed direct in the ground without any additional structure apart from the excavation required for its accommodation. The only limitation is that the case must be accurately located so that the jointing chamber is correctly aligned relative to the main cable.

The Installation of Loading Coils in Cable Splices

The size of the Stanelec long distance type of coil is such that it lends itself to the insertion of the coils in a cable splice, thus providing a means of installation which is very advantageous when only a few circuits are to be loaded.

There are two methods of installing the coils, one being to mount them on an insulating dowel rod and the other to box them in a metal canister. The first of these methods is shown in Figure 32 where four coils are mounted on the dowel rod which is then attached to ends of the main cable sheath and the structure sealed by means of a lead sleeve. With such a method of installation it is imperative that there should be no conducting material connected to the sheath and passing through the "eyes" of the coils, as this would form a closed loop with the lead sleeve and act similarly to a short circuiting winding around the coils. This method of installation is used for cables containing few conductors; approximately six coils can be accommodated without the joint becoming unwieldy.

The other method involving the use of a splice mounting canister is shown in Figures 33, 34, and 35, from which it will be seen that the coils are placed each in a separate compartment of a metal box which is filled with compound and sealed by soldered joints, connection to the coils being made by means of lead covered quads, the sheaths of which are lead sealed at the points where they enter the box. When in the splice the box is bound to the cable conductors which are protected by means of a textile wrapping. It is possible to encase up to five coils in each canister and two such canisters may be installed in one splice.

The cable splice canister method of installation is one which is applied when it is desired to load a few circuits in a large cable such as may occur when music or other special circuits have

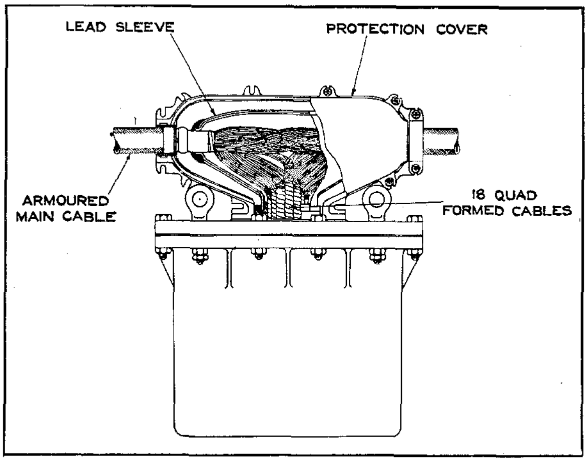


Figure 30—Method of Connecting a Stubless Case to the Main Cable.

to be loaded at points midway between the normal voice frequency loading points.

Both types of equipment will withstand the operations involved in making the joint although a certain amount of care is necessary to avoid undue heating when making the wiped joint between the lead sleeve and the cable sheath.

Loading Coil Installation in Exchange Buildings

It is occasionally necessary to install a number of loading coils inside an exchange or repeater station and under these circumstances the coils are treated exactly like repeating coils and installed in normal repeating coil cases which can be mounted on the standard apparatus racks.

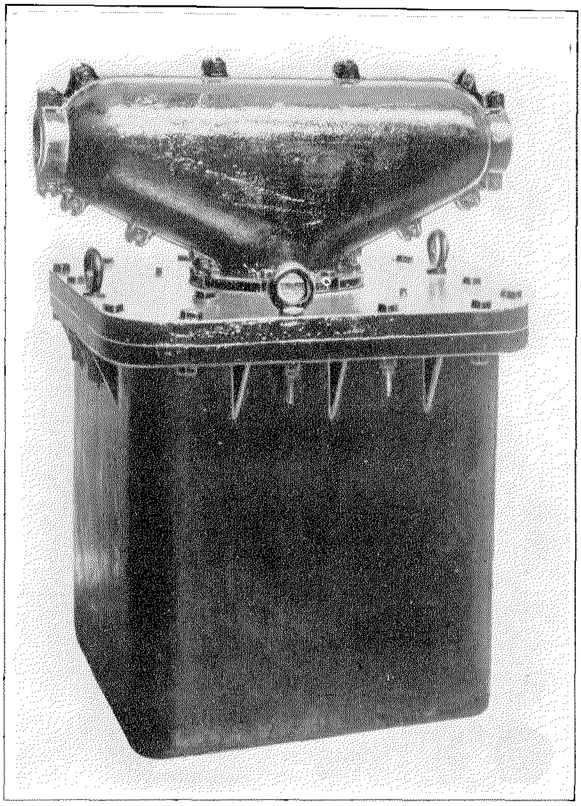


Figure 31—Stubless Loading Coil Case With Joint Protection Cover in Position.

Table VI

Code Number	Maximum Capacity of Case		Dimensions Millimetres						Approximate weight with coils Kilograms
	Units	Coils	Height to top of Cover	Height to Main Cable Centre	Total Height	Case Width	Case Length	Length of Protection Cover	
010-A	144	432	730	985	1145	755	755	880	1010
010-B	108	324	600	855	1015	755	755	880	860
010-C	72	216	475	695	850	755	755	745	710
010-D	36	108	345	565	720	755	755	745	540
011-A	72	216	730	950	1105	450	755	745	710
011-B	54	162	600	820	975	450	755	745	635
011-C	36	108	475	695	850	450	755	745	540
011-D	18	54	345	565	720	450	755	745	465
013-A	24	72	450	640	760	350	755	560	425
013-B	12	36	345	535	655	350	755	560	375

Conclusion

In preparing this paper one of the main objectives has been an attempt to counteract the divergence of viewpoint which has resulted from regarding the apparatus as a separate unit rather than as a part of the complete system. This divergence has been taking place gradually over a period of many years and has given rise to false evaluations.

It seems quite evident that past designs have merged successfully into a definite evolutionary line of progress which at each stage has provided a product adequate for its particular period.

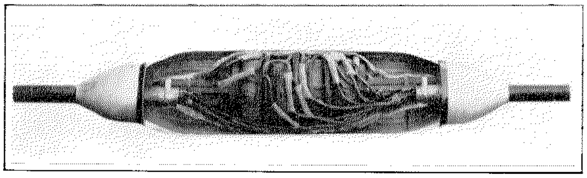


Figure 32—Dowel Method of Splice Installation.

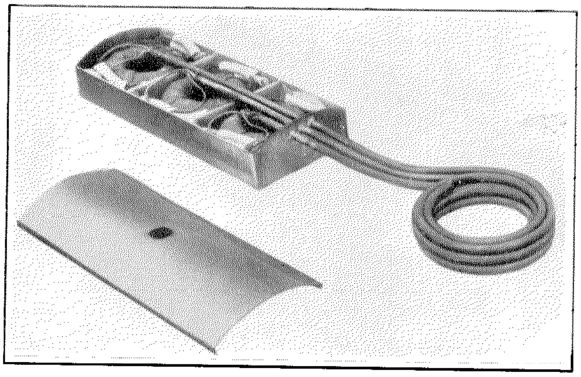


Figure 33—Cable Splice Canister—Open.

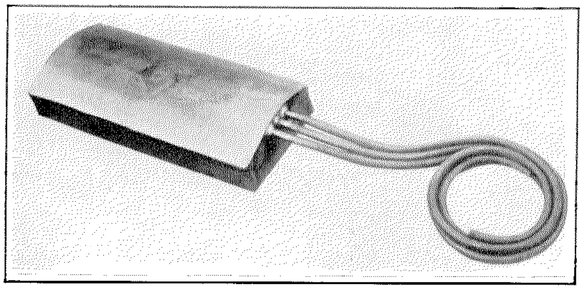


Figure 34—Cable Splice Canister—Sealed.

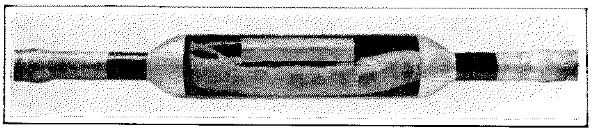


Figure 35—Cable Splice Canister—Installed.

Bibliography

T. Shaw and W. Fondiller, "Development and Application of Loading for Telephone Circuits," *Electrical Communication*, Vol. IV, No. 4, and Vol. V, No. 1.

W. Fondiller, "Commercial Loading of Telephone Cable," *Electrical Communication*, Vol. IV, No. 1.

H. Jordan, "Ferromagnetic Constants for Weak A. C. Fields," *Elektrische Nachrichter Technik*, Vol. I, No. 7.

W. Ehlers, "Loading Coils with Iron Dust Cores," *Elektrische Nachrichter Technik*, Vol. II, No. 5.

B. Speed and G. W. Elmen, "Magnetic Properties of Compressed Powdered Iron," *Proceedings A. I. E. E.*, June, 1924.

W. J. Shackleton and I. G. Barber, "Compressed Powdered Permalloy," *Proceedings A. I. E. E.*, April, 1928.

H. D. Arnold and G. W. Elmen, "Permalloy," *Journal of the Franklin Institute*, Vol. 195, No. 5.

G. W. Elmen, "Magnetic Alloys of Iron, Nickel and Cobalt," *Bell System Technical Journal*, Vol. VIII, No. 3.

W. Fondiller, "Developments in Communication Materials," *Bell System Technical Journal*, Vol. IX, No. 2.

W. Deutschmann, "Optimum Dimensions for Loading Coil Cores," *Telegraphen und Fernsprech Technik*, June, 1931.

W. Deutschmann, "Flutter Effect in Loading Coils," *Wissenschaftliche Veroffentlichungen aus dem Siemens-Konzern*, Vol. VIII, 1929.

Hongkong-Canton Toll Telephone Cable

By P. T. CAREY
China Electric Company

and R. E. BURNETT
International Standard Electric Corporation

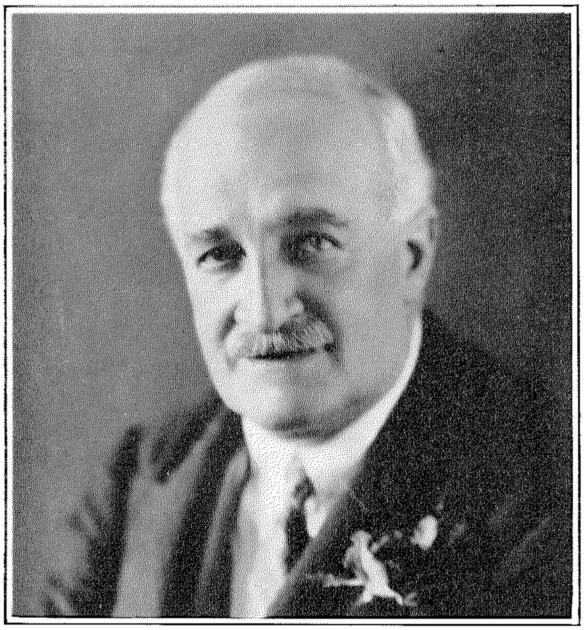
A NEW era of rapid communication in China was inaugurated on September 1, 1931, when long distance telephone communication between Hongkong and Canton was officially opened by His Excellency Sir William Peel, K.B.E., K.C.M.G., Governor of Hongkong, calling His Excellency Lam Wan Koy, Chairman of the Kwangtung Provincial Government in the presence of a distinguished gathering of officials and business representatives of the Communities of Hongkong and Canton. Sir William proceeded:

"I am very glad to have this opportunity of speaking direct to you on the occasion of the inauguration of the long distance telephone from Hongkong to Canton. On behalf of those present here, who include members of Council and the Directors of the Telephone Company, I send hearty greetings to you all. I am sure that you will join me in congratulating the Directors on having carried out this work so expeditiously, and on having provided yet one more bond of union between this Colony and Canton. We all wish the undertaking every success."

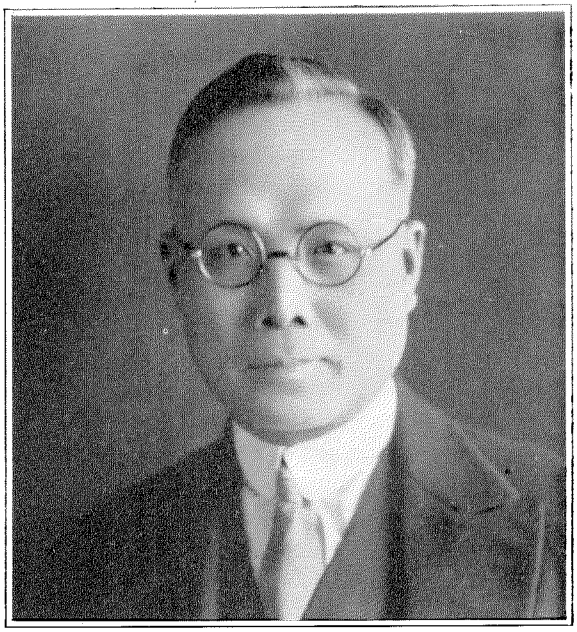
His Excellency Lam Wan Koy, replying to Sir William Peel, said:

"It gives me great pleasure to speak with you through direct means of communication which is now made possible by the inauguration of the long distance telephone. This new service not only marks a long stride in the improvement of commercial facilities, but above all will serve happily to strengthen the tie of friendship between Canton and Hongkong. Indeed it is most befitting for both of us to extend our best wishes for the success and prosperity of this new under-

Scene in Hongkong at Opening Ceremony of the Hongkong-Canton Toll Cable.



His Excellency Sir William Peel, K. B. E., K. C. M. G., Governor of Hongkong. (Photograph by Kobza, Hongkong).



His Excellency Lam Wan Koy, Chairman of the Kwangtung Provincial Government.

taking. May I also take this opportunity on behalf of those present here to send you and other friends in Hongkong our sincere greetings."

After the exchange of greetings, another important feature of the inauguration ceremony was the sending and receiving of photographs (Figure 1) and Chinese documents by means of picture transmission apparatus. The presence of Mr. M. Kobayashi of the Nippon Electric Company, one of the inventors of the system used, added interest to the occasion. The operation of Creed teleprinters, whereby messages were typed in Hongkong and simultaneously transmitted to and received in Canton, was also demonstrated.

The city of Canton is situated on the banks of the Pearl River about 100 miles from its mouth and is the largest and most important trading centre in Southern China. Capital of the province of Kwangtung, it is destined by its position to dominate the trade of the surrounding country, and under the leadership of its progressive and enlightened government exerts a tremendous influence both politically and economically throughout South China.

The Crown Colony of Hongkong is an island, with an area of 32 square miles, ceded to Great Britain by China in 1841, in addition to the peninsula of Kowloon on the mainland making a total area of 390 square miles, with an estimated population of 900,000. The Colony is an important British Station of great strategic value, and is one of the greatest transshipment ports in the world.

Since Hongkong is situated at the mouth of the Pearl River, it may be called the gateway of South China. Through it, practically all trade to and from Canton passes so that the necessity of close co-operation between the two ports is evident.

Canton and Hongkong are connected by a railway, while several lines of river steamers provide an alternative route. Until recently, however, the only other form of communication was the telegraph.

It had long been felt that it was highly desirable to provide direct telephone communication between the two cities and this was made feasible when the China Electric Company to the order of the Canton Municipality installed an up-to-date automatic telephone system in that city. After prolonged negotiations between the Canton Municipality and the Hongkong Telephone Company, an agreement was reached on September 2, 1930, jointly to order an up-to-date long distance telephone cable connecting the two cities.

General Description

The cable consists of 10 quads of 1.6 mm. wire, and was designed to have the low capacity of 0.0483 microfarads per mile, giving a loss of 0.1062 decibels per mile. Figure 2 shows the cross section of the cable. Its design is such that it was possible to avoid providing a repeater station halfway and thus obviate the objection of maintenance difficulties in the absence of a town located in a suitable position for a repeater station. All circuits are loaded; the side circuits with 253 millihenrys and the phantom circuits with 105 millihenrys on an average spacing of 2,182 yards. The cable and loading coils were manufactured by Standard Telephones and Cables, Limited, London.

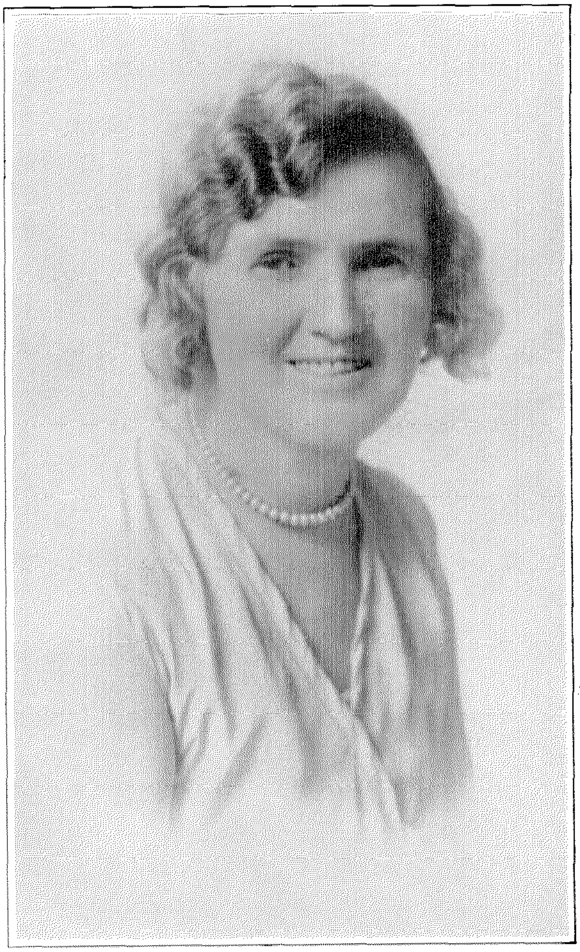


Figure 1—Mrs. P. T. Carey. Transmitted Over the Hongkong-Canton Telephone Cable from Canton to Hongkong.

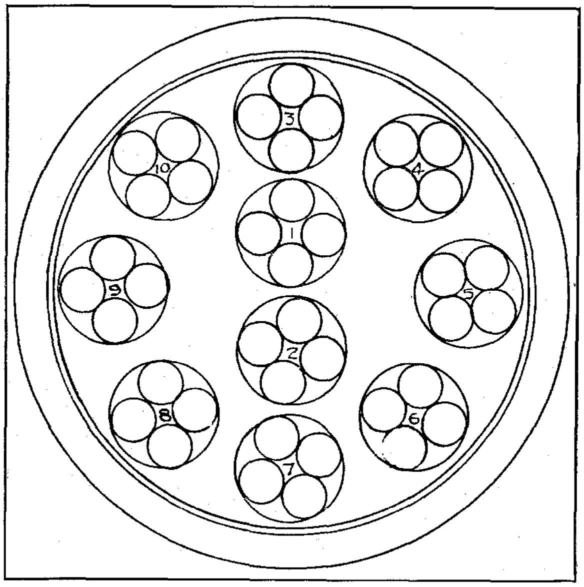


Figure 2—Cross Section of Hongkong-Canton Toll Cable.

For the major part of its total length of 116 miles the cable lies along the right of way of the Canton Kowloon Railway. From the Exchange building in Canton, the route runs through the city streets for about three miles until it joins the railway on the outskirts of the city. This portion of the cable is laid directly in the footways at a depth of 2 feet, the cable being steel tape armoured (Figures 3 and 4). Bricks are laid over the cable as a warning to subsequent excavators. After joining the railway the cable follows it closely as far as a point about four miles south of the British frontier, where it leaves the railway owing to the difficult nature of the country, and follows the highway for a distance of about 12 miles. It then rejoins the railway which it follows until the outskirts of Kowloon are reached, where it enters the duct system of the Hongkong Telephone Company. A diversion is made into the Kowloon exchange of the Telephone Company whence it goes in duct to the harbour's edge. The harbour is crossed by a submarine cable (Figure 5) and then by duct line to the main Hongkong Telephone Exchange.

With the exception of the short sections in the Hongkong Telephone Company's duct, the

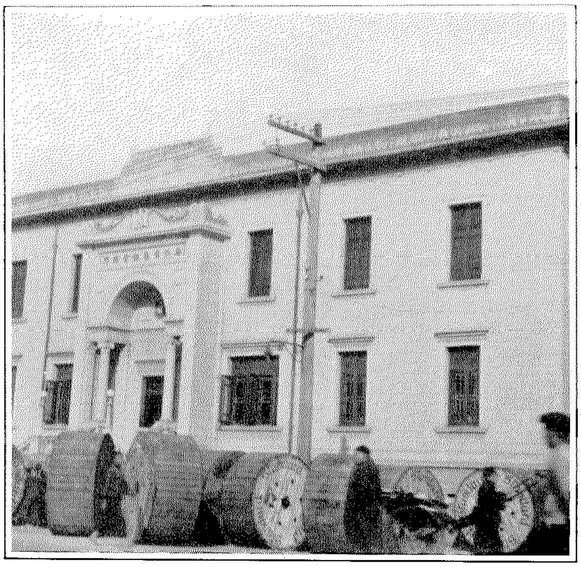


Figure 3—Canton Telephone Exchange Showing Toll Cable Drums.

cable is armoured and buried directly in the ground. In Chinese territory it was considered inadvisable to cross rivers or streams by means of the railway bridges owing to the possibility of their being demolished in times of unrest, and all rivers and streams of any size therefore were crossed by means of special water cable. The cable in these sections is provided with a steel wire armouring, the remainder of the cable being armoured with double steel tape. The depth of trench throughout is two feet except in certain sections of the highway where extensive rock was encountered. Here the depth of the trench was reduced to twelve inches and a protective layer of concrete six inches thick was placed over the cable.

Owing to the varied nature of the country, the survey had to be carried out with great care. Figure 6 shows a section of the route. For the first 50 miles from Canton the route runs through flat low-lying country which forms part of the basin of the East River. This district is subjected to heavy floods during the summer and the many streams which intersect it may become torrential in volume after heavy rain. As the cable was laid under the bed of these streams, considerable care had to be taken to ensure that no damage would occur in times of flood. At all the larger rivers the cable is not only anchored in the river bed by means of heavy weights, but also on each bank by means of cross beams clamped to the armour and buried in concrete. Throughout this portion the cable route runs at the foot of the railway embankment. The latter section of the route in Chinese territory runs through hilly country, which considerably increased the difficulties of cable placing. In some places considerable deviations from the railway had to be made as the ground in its immediate vicinity was too steep and rocky to provide a suitable site for the cable trench.

In the British Section the cable route had to be very carefully chosen on account of storm damage to which this section is subject.

The terminating arrangements at each end are of the simplest. There being no repeaters at either end, the cable is terminated by a sealed cable terminal which provides a U link disconnecting point between the cable and the office wiring. From the cable terminal the circuits are wired to the repeating coils and thence direct to the toll board. The toll boards at each end are of similar design, that at Canton being manufactured by the Bell Telephone Manufacturing Company, Antwerp, and employing specially

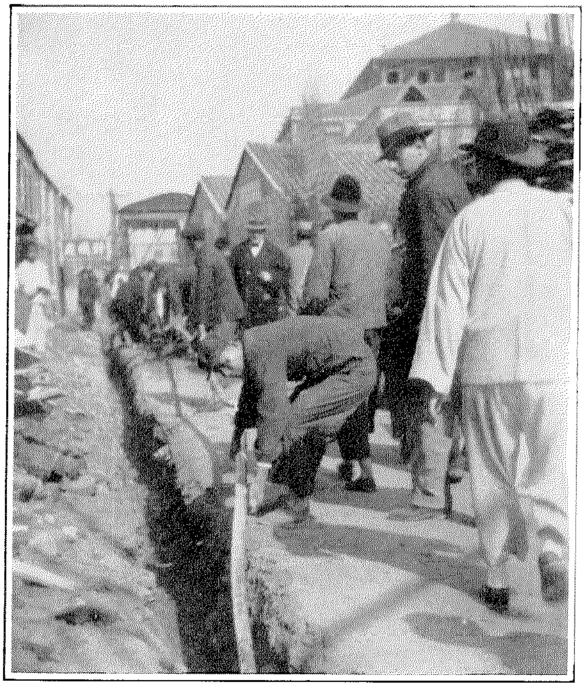


Figure 4—Placing the Cable in Canton.

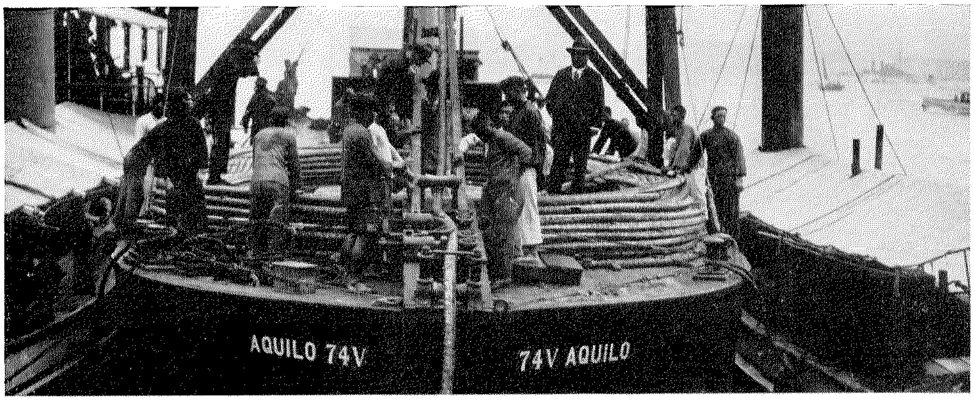


Figure 5—Submarine Cable on Lighter Ready to Start.

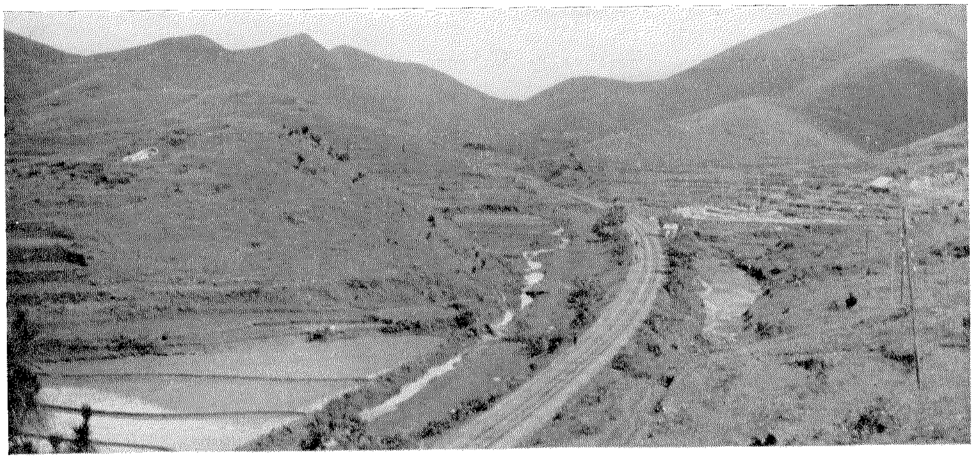


Figure 6—Typical Section of Cable Route Along the Railway in Chinese Territory.

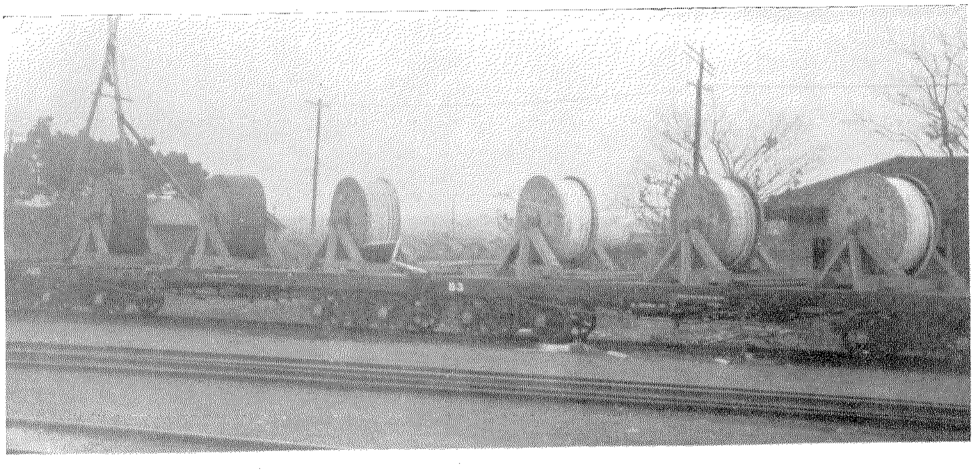


Figure 7—Cable Train.

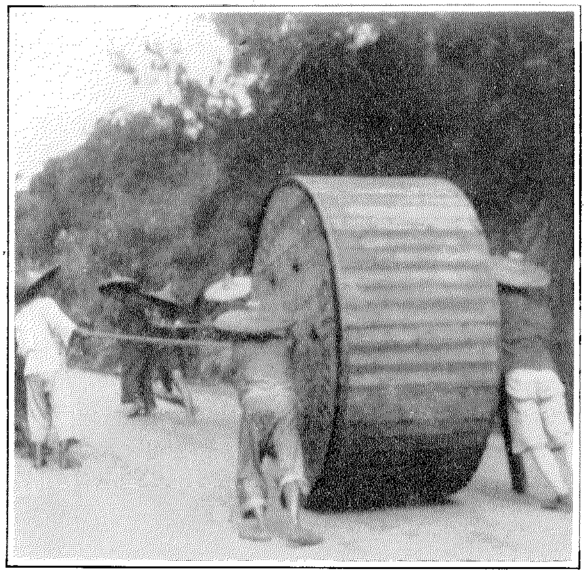


Figure 8—Distributing Drums Along Road in British Territory.

designed circuits to give a "no delay" service and to permit of connections being established with the automatic subscribers over the regular switches.

Submarine Cable

The submarine section across Hongkong harbour from Hongkong to Kowloon is of similar type to the normal land cables but is protected by brass tape and heavy steel wire armour. It was manufactured in one length of 2,200 yards and was balanced in the factory. The cable was laid as soon as possible after arrival. The laying of this section was carried out by the Hongkong Telephone Company. The length of the submarine cable as laid is 1975-1/3 yards.

Installation

In the railway sections the cable was laid direct from the railway, a series of flat cars having been fitted with trestles to take a maximum of 10 drums. Along the roadway both in Canton and in the British section, the cable had to be handled by means of rollers propelled by man power, since the roads were not sufficiently strong to take the combined weight of a cable drum and cable laying truck. About three miles from Kowloon the cable passes through a railway tunnel about 1½ miles long and is supported on reinforced concrete bearers built into the tunnel wall. A loading point which occurs in the tunnel was formed by building a small recess in the wall of the tunnel just large enough to contain the loading coil case (Figures 7, 8 and 9).

The joints are buried in the ground and protected by cast iron protection boxes. The load-points in general consist of small brick or concrete jointing chambers with a pit sunk in the floor which contains the loading coil case.

The installation was carried out with English testers supplied by Standard Telephones and Cables, Limited, and Chinese jointers. As the number of trained Chinese jointers available was not sufficient to secure the progress required it was necessary to train some additional men who were given a short intensive course in a school, their training having been completed in the field under close supervision.

The greatest difficulty which had to be contended with was the absence of any rapid means

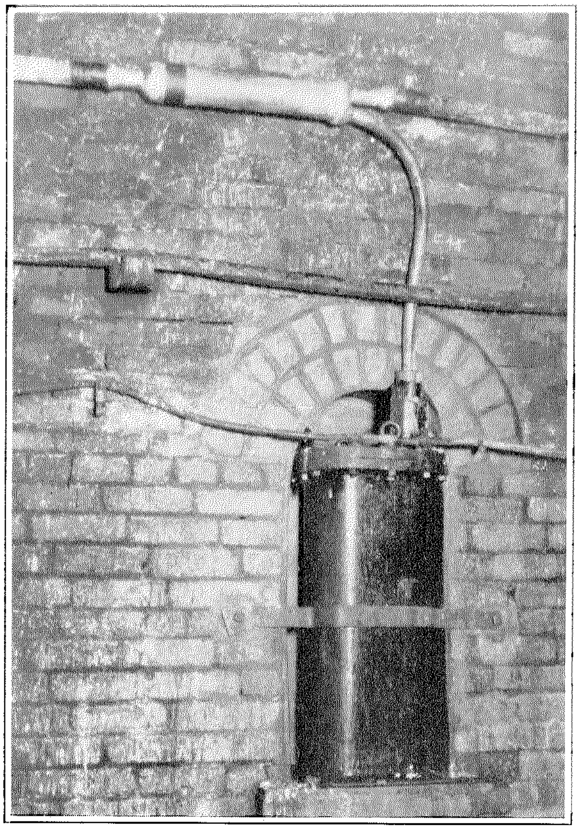


Figure 9—Loading Point in Tunnel.

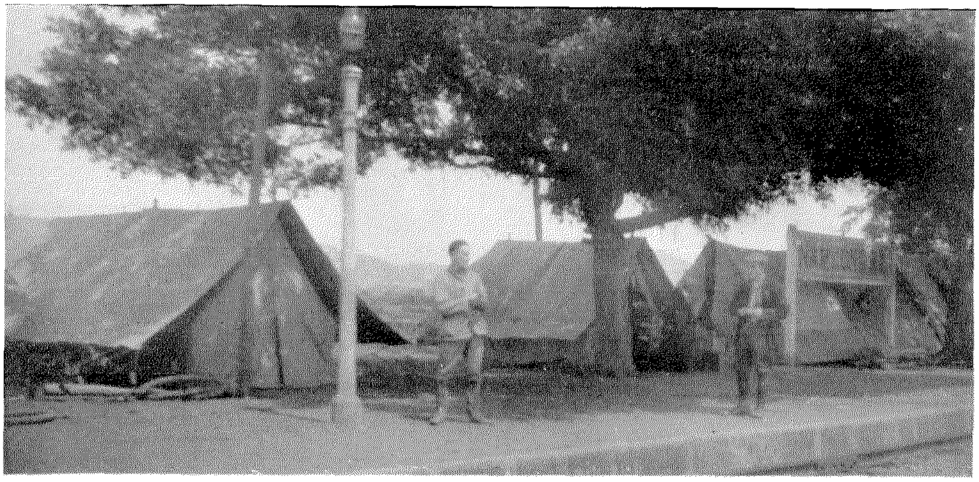


Figure 10-a—Splicers' Camp at Nam Kong.

of transport. The railway line is far from any roads and for the majority of stations there are at the most only two trains each way per day. It therefore became necessary for the testers and the splicing gangs to camp along the railway as near to the job as possible. A local station was always selected for the sites of these camps. Transport of materials from camp to work site was effected by means of gangs of coolies and push trolleys. Each camp also had a "pump trolley" for the use of the testers. Since the country was more or less infested with bandits, a detachment of national guards was detailed to each camp for protection (Figures 10-a and 10-b). Actually only one case of banditry occurred, one squad having been relieved of their cash.

The cable is balanced in accordance with the well-known cross splicing method. Test splices were made in each loading section for capacity unbalance reduction, and the phantom and side circuit capacity deviations were reduced at the

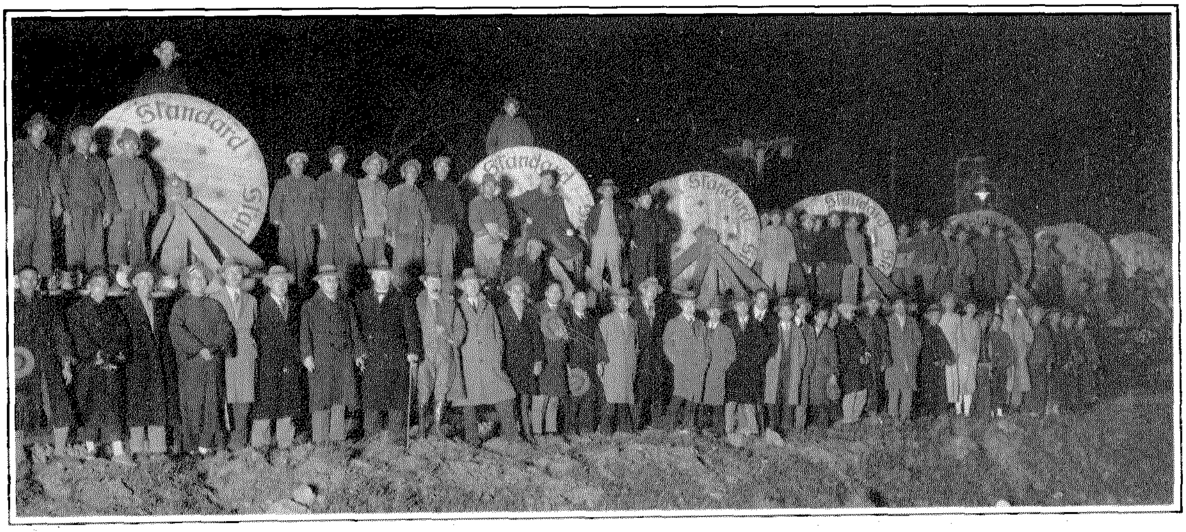


Figure 10-b—Cable-laying Train. First Night Out Just Before Starting Laying.

TABLE NO. I

Crosstalk Summary Hongkong-Canton Cable—116 Miles

1.6 mm. H. 253—105		Near End				Far End			
		Average		Maximum		Average		Maximum	
		C. T. Units	Népers	C. T. Units	Népers	C. T. Units	Népers	C. T. Units	Népers
Crosstalk between circuits in the same quads	Ph-S	243	8.4	400	7.9	128	8.9	160	8.7
	S-S	109	9.1	200	8.4	80	9.4	120	9.0
Crosstalk between circuits in different quads	Ph-Ph	103	9.2	200	8.4	68	9.5	135	8.9
	Ph-Ph	158	8.6	300	8.1	96	9.2	160	8.7
	Ph-Ph	120	9.0	400	7.9	83	9.4	160	8.7

centre splice of each loading section. The usual direct current tests were made for resistance and insulation. Each loading section was pressure tested with compressed air for 24 hours before loading was carried out.

As stated previously, the cable is fully loaded. At the loading splices circuit capacity matching was carried out so as to provide the maximum capacity regularity possible.

The first length of cable was placed on January 17, 1931, and it was realized that rapid progress would have to be made in order to complete the section before the advent of the rainy season with consequent liability to flooding. It was estimated that to do this some 45 loading sections would have to be completed by the end of April. Unfortunately very heavy rains were experienced early in April with the result that sections of the route were under four feet to ten feet of water. It was necessary to leave this section out temporarily and return to it when the flood level had dropped. Even then the splices in this section were made under very bad conditions (Figure 11). In spite of these and other delays due to bad weather, the cable was

TABLE NO. II

Average attenuation constants Hongkong Canton Cable
(Measurements at 800 c.p.s. and +15° C.)

Type of Circuit	db/mile	Népers/mile
Side	0.0823	0.00946
Phantom	0.0774	0.00890

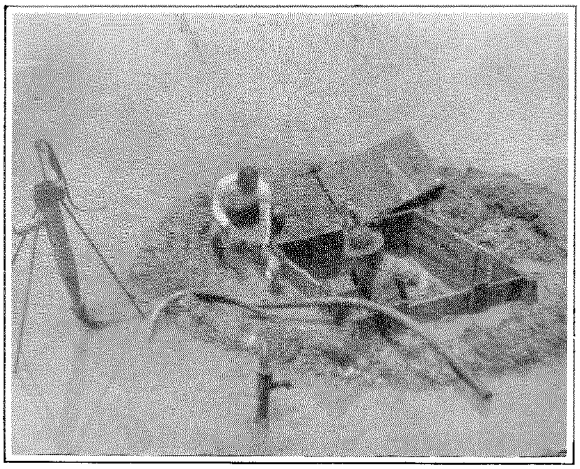


Figure 11—A Laying Point Protected by a Coffer Dam From the Floods.

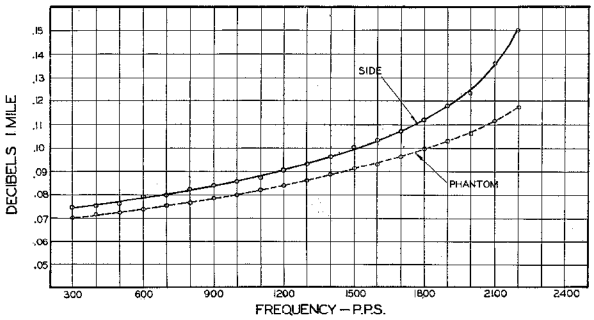


Figure 12—Hongkong-Canton Toll Cable. Attenuation Frequency Curve.

completed on time and successfully cut into service on September 1, 1931.

Measurements and Results

A series of measurements were made on the completed cable to ascertain that the cable and loading coils were satisfactory. These tests consisted of measurements of insulation, crosstalk, attenuation, and impedance.

Crosstalk tests were made for near end crosstalk from each end of the cable and for far end crosstalk from one end only. Table I shows a summary of the results obtained.

Measurements of attenuation were made on

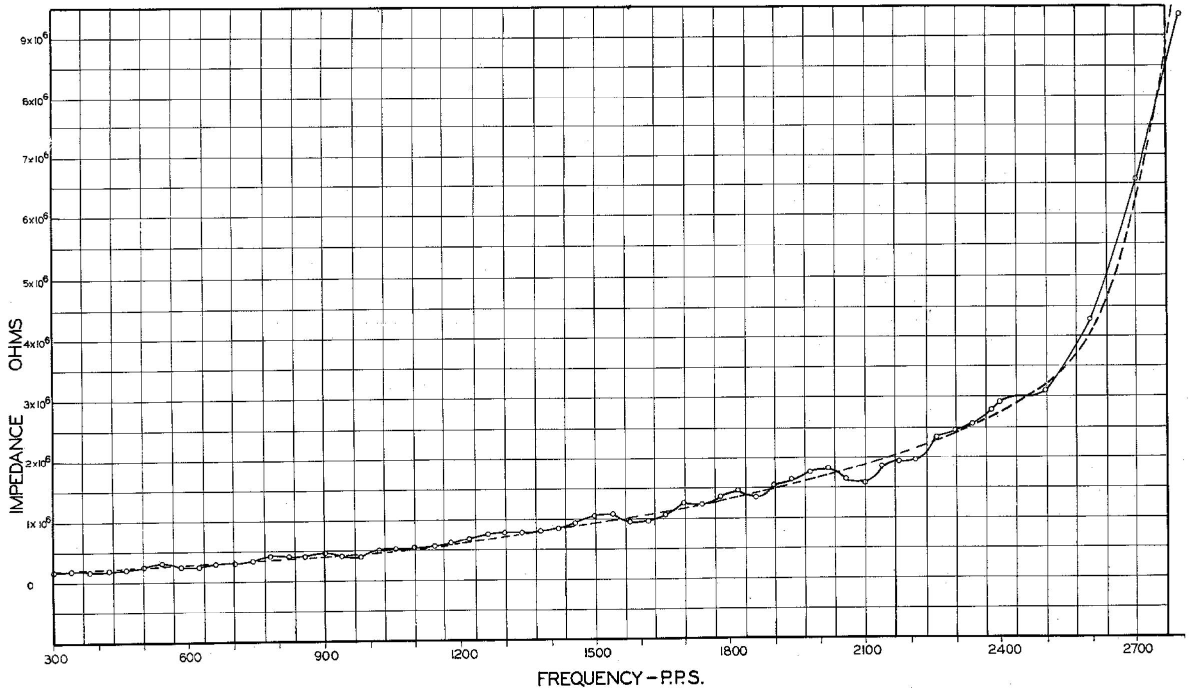


Figure 13—Hongkong-Canton Toll Cable. Impedance Frequency Curve, Side Circuit.

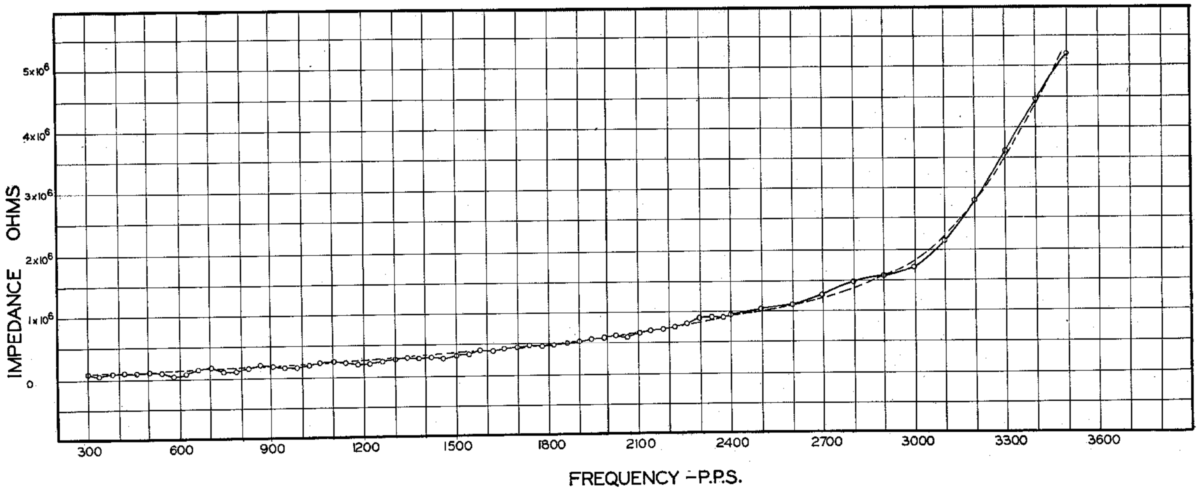


Figure 14—Hongkong-Canton Toll Cable. Impedance Frequency Curve, Phantom Circuit.

all circuits at 800 c.p.s. Table II gives a summary of the results.

Attenuation-frequency runs were made on representative circuits. A typical curve is given in Figure 12.

Impedance curves were taken on representative circuits. Typical examples are shown in Figures 13 and 14.

The above brief review gives the more important features of a cable which though in itself of small size, is destined to be of considerable importance in the telephone development of China by reason of its being the first long distance telephone cable to be installed in that country.

ERRATUM

Electrical Communication, Vol. X, No. 2, October, 1931.

Page 88, Table, column 2, "Outgoing to Tandem Circuits," substitute, left to right: 5, 74, 370, 76, 380.

The UNDERSEAS DIVISION of a Great Communication System

●

Two vast cable organizations form the underseas division of the International system . . . Commercial Cables and All America Cables.

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Working in perfect harmony with Postal Telegraph and Mackay Radio, these two great cable organizations help to establish the International System's achievement of coordinated world-wide record communications under a single management.

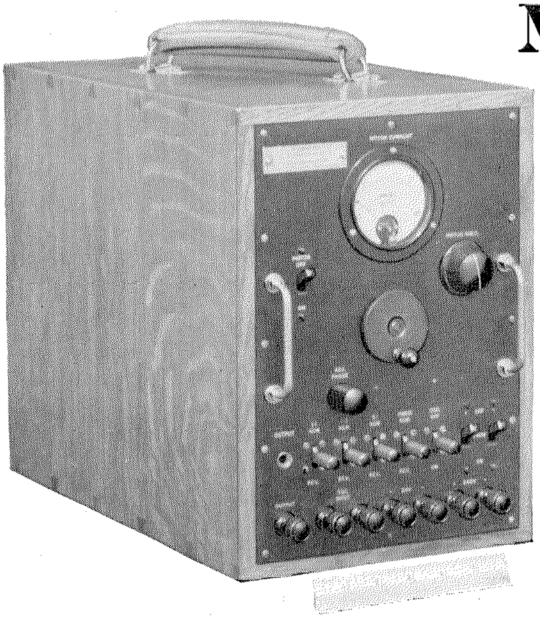
THE INTERNATIONAL SYSTEM

Commercial Cables *All America Cables*

Postal Telegraph *Mackay Radio*

TELEGRAPH DISTORTION MEASURING SET

(PORTABLE)



●

The Test Transmitter produces distortion-free telegraph signals and provides a reference standard of measurements.

The Test Receiver, using a cathode ray oscillograph, produces light flashes on a scale marked directly in percentage distortion.

The operation of mechanical transmission systems is affected directly by the "time distortion" which causes signals to arrive too early or too late. It must be measured in order that faulty components can be corrected by a process of elimination.

Hence the STANDARD TELEGRAPH DISTORTION MEASURING SET.

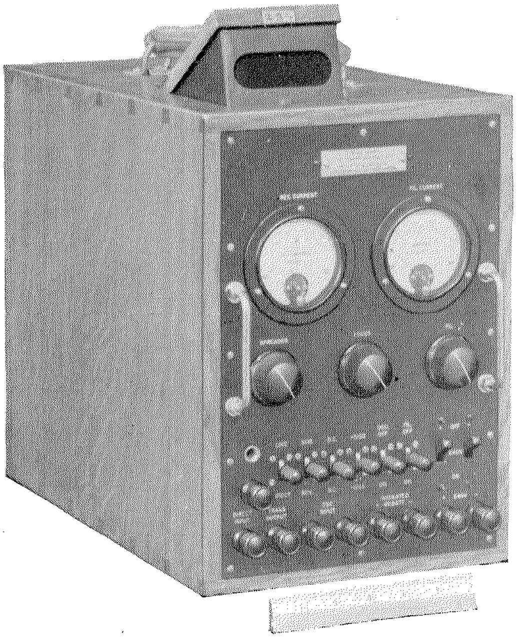
It measures directly the difference in time between the earliest and the latest signals, indicating their arrival, with reference to perfect reception, on a clearly-readable scale.

Its use is indispensable to up-to-date telegraph operation in accordance with the highest modern standards.

●

The Test Transmitter and the Test Receiver are each 16 in. by 9¼ in. by 13 in., the transmitter weighing 55 lb. and the receiver 35 lb.

Power for the transmitter may be drawn from the 240 or 160 volt telegraph battery and the regular 24 volt battery of the system. The receiver requires 240 or 160 volts supply in common with the transmitter, as well as a separate insulated 4-volt battery of from 20 to 40 ampere-hour capacity for the cathode ray.



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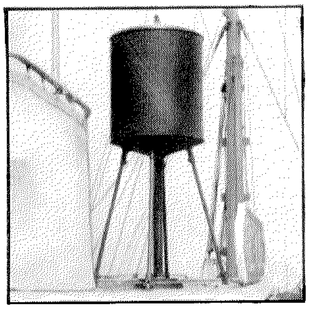
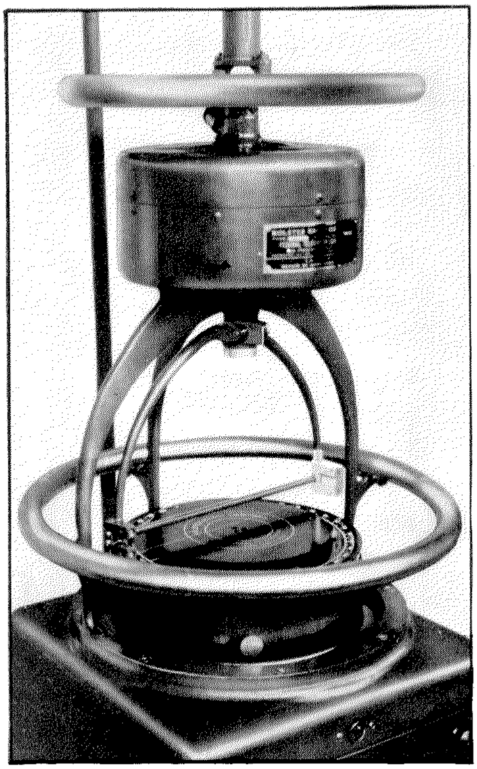


● *The loop of the Kolster Radio Compass is mounted in a protective metal covering directly above the ship's navigating room.*

RADIO DIRECTION FINDER



● *The hand wheel which rotates the loop and sight wires above the compass card can be turned with the pressure of two fingers...in any weather.*

●

The Radio Direction Finder today is one of the most important modern inventions for the protection of life and property at sea.

Radio Direction Finders may be relied upon to be accurate to within 1° of arc. Since they depend for their operation on radio bearings, their employment is completely independent of wind, weather, or visibility conditions. These advantages give them a unique position as compared with all other aids to navigation. In addition they have a greater range than any visible method of operation even in the finest weather and under the most favorable conditions of visibility.

The Kolster Radio Compass (Direction Finder) is manufactured and distributed by the Federal Telegraph Company, a subsidiary of the Mackay Radio and Telegraph Company which is the radio-telegraph division of the International Telephone and Telegraph System of world-wide telegraph communications.

The International Marine Radio Company, Limited, another associated company of the International Telephone and Telegraph Corporation, also has specialized in the supply of Radio Direction Finders. In developing its product it has co-operated with the designers of the Kolster Radio Compass and the Sperry Gyroscope Company.

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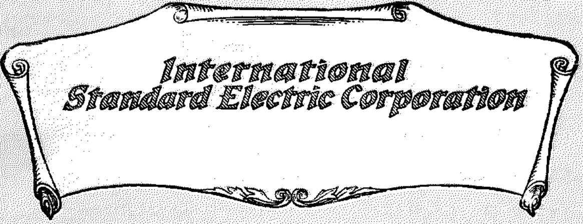
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ELECTRICAL COMMUNICATION

INDEX TO VOLUME 10

1931—1932

ELECTRICAL COMMUNICATION

Volume 10, 1931—1932

INDEX

		PAGE
Alternative Trunking For Telephone Traffic in a Multi-office Area	October, 1931	86
Appleyard, Rollo: A Link With Oliver Heaviside	October, 1931	53
Automatic Concentration Unit For Printing Telegraph Circuits, An, by G. S. Vernam	April, 1932	200
Automatic Device For Recording, Correcting and Analysing Articulation Results, An, by John Collard	January, 1932	140
Balancing Cables By Inductive Networks, by M. I. Pupin	April, 1932	218
Beckman, Carl: Pneumatic Ticket Distributing Systems For Toll Boards	January, 1932	134
Braem, L. A.: A System For Simultaneous Telephony and Telegraphy Over Long Distance Small-Gauge Cables	October, 1931	71
Brief Biography of Mr. Kankichi Yukawa, A	January, 1932	139
Burnett, R. E.: Hongkong-Canton Toll Telephone Cable	April, 1932	237
Carey, P. T.: Hongkong-Canton Toll Telephone Cable	April, 1932	237
Chapman, S.: Telephone Condensers	July, 1931	39
Collard, John: An Automatic Device For Recording, Correcting and Analysing Articulation Results	January, 1932	140
Connery, A. F.: Direct Printing Over Long Non-Loaded Submarine Telegraph Cables	April, 1932	210
Developments in Start-Stop Telegraphy—The New Creed Printer	October, 1931	77
Direct Printing Over Long Non-Loaded Submarine Telegraph Cables, by M. H. Woodward and A. F. Connery	April, 1932	210
Early Television and Picture Transmission Proposal, An	July, 1931	34
Earthquake Disaster and Damages to the Long Distance Telephone Cable Line in Japan, 1930, An, by Sannosuke Inada	October, 1931	67
Electrical Communication in 1931	January, 1932	101
Hinton, L. T.: The Spread Sideband System on Short Wave Telephone Links	October, 1931	60
Hongkong-Canton Toll Telephone Cable, by P. T. Carey and R. E. Burnett	April, 1932	237
Inada, Sannosuke: An Earthquake Disaster and Damages to the Long Distance Telephone Cable Line in Japan, 1930	October, 1931	67
Inada, Sannosuke: Public Service of Phototelegraphy in Japan	July, 1931	26
In Memoriam—Eduard Otto Zwietusch	October, 1931	95
Kaye, J. B.: Modern Loading Equipment (Part 1)	January, 1932	147
Kaye, J. B.: Modern Loading Equipment (Part 2)	April, 1932	223
Kristiansen, M. L.: Ten Years of Full Automatic Telephone Service in Oslo	July, 1931	36
Lining Up Broadcasting Circuits, by E. K. Sandeman	January, 1932	131
Link With Oliver Heaviside, A, by Rollo Appleyard	October, 1931	53

		PAGE
Lloyd, J. A. H.: A New Voice Frequency Telegraph System	April, 1932	184
Maddison, R. E. W.: Telephone Condensers	July, 1931	39
McCurdy, Bruce H.: Telephone Problems and Progress in Rumania	April, 1932	175
Micro-Ray Radio	July, 1931	20
Mirk, D. B.: The Prague High-Power Broadcasting Equipment	January, 1932	106
Modern Loading Equipment (Part 1), by J. B. Kaye	January, 1932	147
Modern Loading Equipment (Part 2), by J. B. Kaye	April, 1932	223
Montgomery, A. W.: A New Voice Frequency Telegraph System	April, 1932	184
New Voice Frequency Telegraph System, A, by J. A. H. Lloyd, W. N. Roseway, V. J. Terry and A. W. Montgomery	April, 1932	184
Ogilvie, G. A.: Telephone Problems and Progress in Rumania	April, 1932	175
Pneumatic Ticket Distributing Systems for Toll Boards, by Carl Beckman	January, 1932	134
Pocock, L. C.: Transmission Testing of Subscribers' Apparatus	October, 1931	82
Practical Value of the Proximity Loss in Parallel Go and Return Conductors, The, by J. K. Webb	July, 1931	22
Prague High-Power Broadcasting Equipment, The, by D. B. Mirk	January, 1932	106
Public Service of Phototelegraphy in Japan, by Sannosuke Inada	July, 1931	26
Pupin, M. I.: Balancing Cables by Inductive Networks	April, 1932	218
Reeves, A. H.: The Single Sideband System Applied to Short Wavelengths	July, 1931	3
Roseway, W. N.: A New Voice Frequency Telegraph System	April, 1932	184
Sandeman, E. K.: Lining Up Broadcasting Circuits	January, 1932	131
Single Sideband System Applied to Short Wavelengths, The, by A. H. Reeves	July, 1931	3
Spread Sideband System on Short Wave Telephone Links, The, by L. T. Hinton	October, 1931	60
Stockholm-Malmö Railway Cable	October, 1931	96
System For Simultaneous Telephony and Telegraphy Over Long Distance Small-Gauge Cables, A, by L. A. Braem	October, 1931	71
Ten Years of Full Automatic Telephone Service in Oslo, by M. L. Kristiansen	July, 1931	36
Telephone Condensers, by R. E. W. Maddison and S. Chapman	July, 1931	39
Telephone Problems and Progress in Rumania, by G. A. Ogilvie and Bruce H. McCurdy	April, 1932	175
Telephone and Telegraph Statistics of the World	July, 1931	45
Terry, V. J.: A New Voice Frequency Telegraph System	April, 1932	184
Transmission Testing of Subscribers' Apparatus, by L. C. Pocock	October, 1931	82
Universal Mounting Plate, The, by L. H. Webb	October, 1931	89
Vernam, G. S.: An Automatic Concentration Unit for Printing Telegraph Circuits	April, 1932	200
Webb, J. K.: The Practical Value of the Proximity Loss in Parallel Go and Return Conductors	July, 1931	22
Webb, L. H.: The Universal Mounting Plate	October, 1931	89
Woodward, M. H.: Direct Printing Over Long Non-Loaded Submarine Telegraph Cables	April, 1932	210
Yukawa, Mr. Kankichi—A Brief Biography of	January, 1932	139
Zwietusch, Eduard Otto—In Memoriam	October, 1931	95